ILLUMINATING ENGINEERING

MAY 1953

Brightness Difference and Suprathreshold Seeing
Color-Rendering Properties of F-Lamps
Design for Dentists' Waiting Room
Realistic Maintenance Factors
Time vs Luminous Ceilings
Improved Sphere Paint
Foundry Lighting

THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

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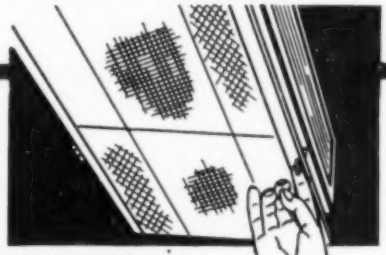
3924	2-48T12 Slimline	Metal
3928	2-96T12 Slimline	Metal



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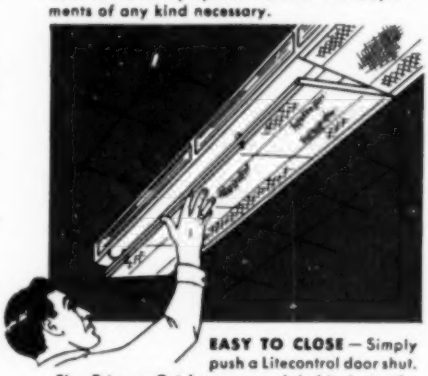

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ILLUMINATING ENGINEERING

THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

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12 Leader Lighting Systems to Make Up "Leader Line"

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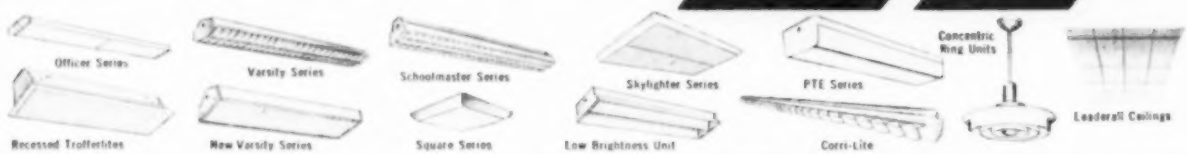
To answer your Question:

"What does this News Mean to Me?"

—a Statement by Benjamin Electric concerning the advantages to you of its acquisition of all these lighting units, hereafter to be known as the BENJAMIN *Leader Line*



The Leader Line in combination with the Benjamin Line makes Benjamin-Leader the largest, most complete industrial *and* commercial lighting line in the world.

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Hoyt P. Steele

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Design for a Dentists' Waiting Room

By PAUL GRAYSON

In this formerly gloomy waiting room the author, an interior designer, had the opportunity of coordinating both lighting and decoration for an atmosphere conducive to relaxation.

IF EVER an area would need effective illumination for a pleasing comfortable atmosphere, it would be the waiting room of a dentists' office. In the room shown, illumination was an especially important factor in this direction, since there were no windows at all; the room was quite small, 10 feet 3 inches by 10 feet 9 inches, with a 9-foot ceiling, and frequently had to accommodate as many as ten patients waiting their turn in the dentist's chair.

The feeling of confinement within a windowless area was solved with the use of a wall-size mural whose subject matter brought depth and openness to the whole area. To further emphasize depth, and to give the illusion of a natural light source, a specially-designed lighted cornice was installed one foot six inches from the ceiling, above the mural. Louver squares in the cornice permit light to be thrown across the ceiling for indirect illumination. Diffusing glass below sends light to the wall mural and at the same time provides 20 footcandles of illumination maintained, for casual reading on the couch below. This unit is lamped with two 51-watt 96-inch T8 white slimlines.

To the left of the couch, a three-way portable table lamp, using 75-100-150 watt lamp, provides supplementary lighting and adds to the decorative effect.

Along another wall, a children's bench is illumi-

This installation took second prize in the 1953 contest conducted by the Central New York Section of I.E.S. for "My Most Interesting Lighting Installation." Mr. Grayson is an interior designer for Neptune Furniture Company, New Rochelle, New York.

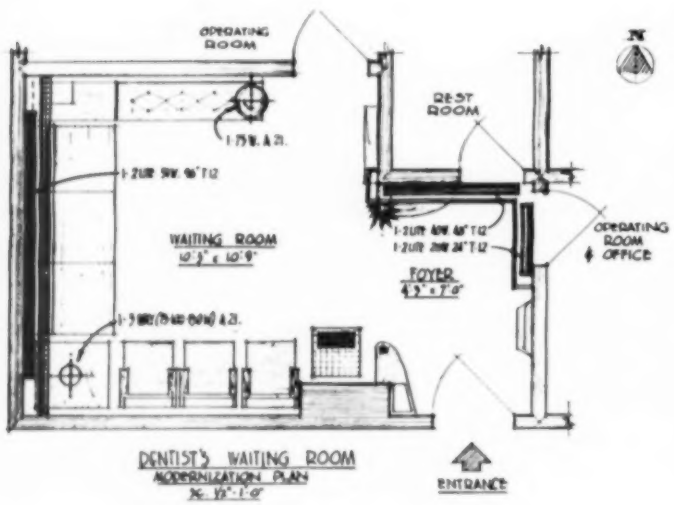
Corner cornice, at right in photo, lights entrance-way, and provides illumination for small package shelf and the mirror unit.

nated with an inverted white enameled bowl fixture mounted six feet above the floor, using a 75-watt lamp. The white plastic "brick" covering on this wall provides excellent reflectance, besides being a practical washable surface for little hands to touch.

Above the plastic material, the wall has been painted a flat sunlight yellow; the ceiling is a light tint of this color. The remaining walls are a soft medium flat gray and the floor covering is also a soft gray for maximum light reflectance.

Installed above the doors to the rest room and one of the operating rooms leading from the entrance foyer is a corner light cornice containing one 2-lamp 24-inch and one 2-lamp 40-watt 48-inch T12 white, instant start fixtures. Besides good lighting for the entrance-way, this provides illumination for a small package shelf and mirror unit. A medium cool blue tone is used on the walls in this area.

Acknowledgment is made to the cooperation of Drs. C. and A. Dreizen, of New Rochelle, New York, whose offices are here described.



Since the room is small in size and there is no window, an illusion of space is created by the wall mural (shown on the previous page).

Brightness Difference— A Basic Factor in Suprathreshold Seeing

By SYLVESTER K. GUTH
A. A. EASTMAN
R. C. RODGERS

IT IS accepted that increasing the brightness of a visual task (up to a limiting value generally well above present-day lighting practice) increases its visibility. Brightness is the most controllable of the four factors of size, contrast, brightness and time, which govern the visibility of an object. In the usual sense, the brightness of a visual task is considered to be the brightness of the immediate background against which the details of the task are viewed. However, changes in background brightness, with changes in illumination, are accompanied by changes in object brightness. It is the brightness difference between the object and its background which becomes a significant index in evaluating the effectiveness of illumination. While the contrast of an object with its background will remain constant at all illumination levels, the brightness difference will increase as the illumination increases.

Let us consider a specific visual task being performed by a worker. It can be defined and described by its size, by the contrast between the details and their immediate background and by the time available for seeing. In any particular visual situation, these factors are constant regardless of the level of illumination. When the level of illumination is increased, the only corresponding changes in the task are the brightnesses of the object and its immediate background. If, in analyzing the improved visibility, only the background brightness is included, no consideration is given to the effect of the illumination upon the object. Thus, it is difficult to develop a general concept of suprathreshold seeing which can be applied to any visual task. Furthermore, it seems to be desirable to be able to relate suprathreshold conditions to a basic and fundamental measurement which does not involve any physical change in the task being viewed. On this basis, measurements of threshold size, contrast or viewing time appear to be inadequate for describing suprathreshold conditions.

Measurement of brightness differences can be related to any visual task and extended to all suprathreshold conditions. It bears a relation to contrast, in that the latter can be considered as relative brightness difference. However, by placing it on a relative basis, the significance of the absolute values of brightness is lost. If contrast and brightness of background are known, the brightness difference can be computed:

$$C = \frac{B_b - B_o}{B_b}$$

$$\Delta B = B_b - B_o = C B_b$$

where C is the contrast and ΔB is the brightness difference between the background brightness, B_b, and the object brightness, B_o. Similarly, the brightness difference can be expressed as a function of the illumination E and the reflectances of the background R_b and the object R_o:

$$\Delta B = E\,(R_b - R_o)$$

Considerable data are available that can be used to check the relationships between threshold and suprathreshold seeing. Many of them are in terms of contrast and background brightness, which can be converted into brightness difference. Nevertheless, it was decided to obtain new data to establish the general trends and validity of these relationships and of the brightness difference concept and its application to appraising suprathreshold visibility.

The first step was to determine the threshold illumination for a series of test objects of equal size but of various contrasts. The objects selected correspond to the letter E of the A.M.A. test chart. They were accurately reproduced by photographic means so that at the viewing distance of 20 feet they subtended visual angles corresponding to line 5 of the A.M.A. chart. Thus, the visual angles of the stroke widths were approximately 2.25 minutes. The overall heights of the letters were five times the stroke widths and subtended visual angles of 11.25 minutes. Physical data pertaining to these objects are presented in Table I. While it is difficult to reproduce these objects accurately, Fig. 1 will aid in visualizing them. High, medium and low contrasts

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AUTHORS: Application Engineering Dept., Lamp Division, General Electric Co., Nela Park, Cleveland, Ohio.

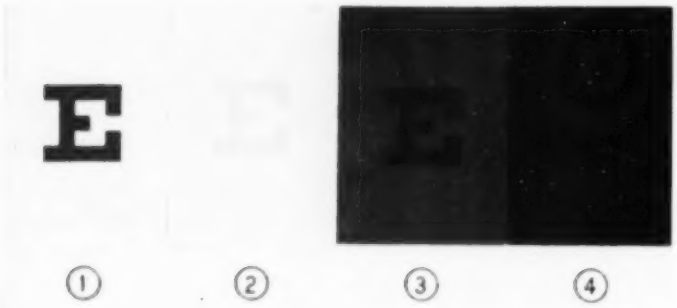

Figure 1. Reproductions of the test objects used in the experiment. From left to right they represent approximately the contrasts of the four letters, 1 to 4, respectively, described in Table I.

TABLE I.—Physical and Observed Threshold Data Pertaining to the Four Letter E Test Objects. Reflectance and contrasts are expressed in per cent, and brightness in footlamberts.

Physical Data	Test Object			
	1	2	3	4
Background reflectance, R_b	85.7	89.8	6.49	4.52
Object reflectance, R_o	2.6	76.3	3.58	3.84
Reflectance difference, ΔR	83.1	13.5	3.11	0.68
Contrast, C	97.0	15.0	48.0	15.0
Threshold Data				
Footcandles	0.044	0.95	2.36	18.4
Relative footcandles	1	22	54	420
Background brightness, B_b	0.038	0.85	0.15	0.83
Object brightness, B_o	0.001	0.72	0.077	0.70
Brightness difference, ΔB	0.037	0.13	0.073	0.13
Relative brightness difference	1	3.5	2	3.5

were obtained with various combinations of background and object reflectances. It will be noted that identical contrasts were obtained with objects 2 and 4 by different reflectance combinations. This pair afforded an opportunity to make a direct comparison of the brightness difference required for the threshold condition for light and dark backgrounds. Objects lighter than their backgrounds were not included because no significant differences have been found for the range of sizes and contrasts usually encountered in typical seeing situations.[1]

Eleven young adult observers — all with normal vision — made a series of observations of the threshold illumination. That is, the illumination was adjusted until the letters were just barely recognizable. The average threshold footcandle levels for the test objects are presented in Table I. It is interesting to compare the results obtained with objects 2 and 4. These objects have identical contrasts but reflectance differences of 13.5 and 0.68 per cent, respectively. The threshold illuminations required for this pair of letters were 0.95 and 18.4 footcandles. The observed brightness differences are equal. Similar results were obtained with a smaller pair of E's but with considerably higher levels of illumination. These data indicate that two visual tasks of identical contrasts having unequal reflectance differences can be brought to an equal level of discrimination by footcandle levels which provide the same brightness difference.

In Fig. 2 are illustrated the relationships between visibility levels, as indicated by the Luckiesh-Moss Visibility Meter, and footcandles for each of the E's. It is seen that the lower contrast objects require considerably higher footcandle levels than the high contrast objects for any given visibility level. For example, for a visibility level of 2, the required footcandles are 1, 24, 52 and 500 which are in approximately the same ratios as the threshold footcandles as presented in Table I. Furthermore, these ratios are practically constant for all visibility levels. In other words, the visibility meter indicates relative footcandles of the same order as threshold observations. These values bear no obvious relationship to the physical data of the objects, though they can be arranged in the same order as the reflectance differences. However, an analysis of other data has indicated that such a relationship is continuous only when either the reflectance of the object or of the background is a constant. For example, the relationship between visibility level and reflectance difference of a series of objects of the same size, all with white (80 per cent) backgrounds, can be represented by a smooth curve. A different curve will be required for a different background reflectance. This probably is the reason why some experimental data presented in terms of contrast appear rather variable. When the data are so presented, different curves will be obtained for identical values of contrast. None of these relationships is unexpected, but they do serve the purpose of emphasizing the importance of the reflectances of the object and its background.

When the data of Fig. 2 are replotted in terms of brightness difference, the curves of Fig. 3 are obtained. In this case the curves for test objects 2 and 4 fall together and the three curves are in the same relative order as the contrasts involved. However, these curves still do not differentiate between

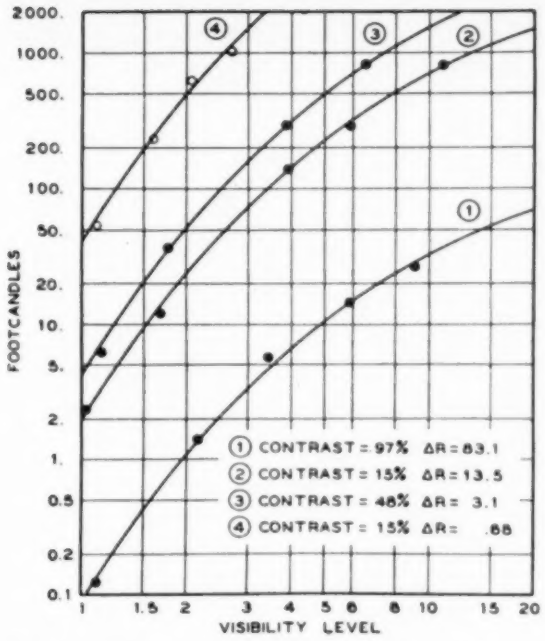

Figure 2. The relationships between footcandles and visibility level for four letter E test objects with various contrasts and reflectance differences.

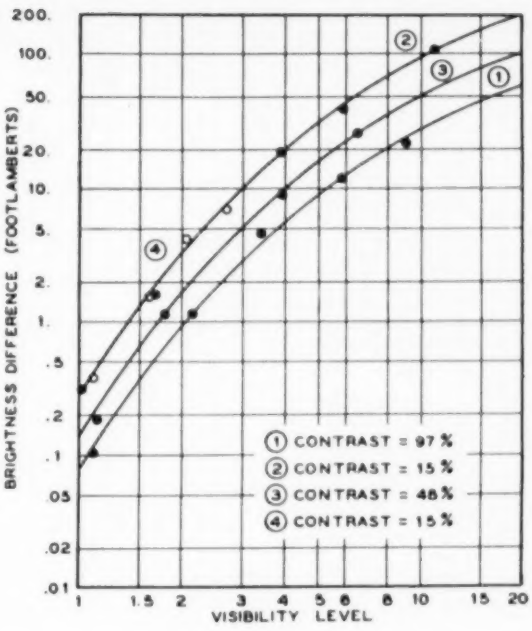

Figure 3. The data of Fig. 2 replotted in terms of a relationship between brightness difference and visibility level.

objects of equal contrasts obtained with different combinations of reflectances. Nevertheless, they do indicate the important point that for a given contrast, brightness difference is a constant for a specific visibility level. This also is illustrated in Table I for threshold values of brightness difference. In other words, the L-M visibility meter rates the objects in the same manner as they are rated on a threshold basis. For example, the relative values of brightness difference from threshold data (Table I) are 1, 2 and 3.5 as compared to 1, 1.8 and 3.5 for the visibility data (Fig. 3).

It is often overlooked that any specific contrast can be obtained with an infinite variety of combinations of background and object reflectances. The data presented in Fig. 4 illustrate how a given visibility level can be maintained with tasks having four different contrasts. Each contrast is obtained with several combinations of background and object reflectances. It is shown that for a particular contrast, however obtained, the illumination must be such that the brightness difference will be constant. All of the data pertain to a visibility level of 5. Data were obtained with 5-minute parallel bar test objects with contrasts ranging from 20 to 95 per cent. For each contrast the background reflectances ranged from white (80 per cent) to dark gray (20 per cent). Appropriate values of object reflectances were selected for the various contrasts.

To maintain any given visibility level for a constant contrast, the brightness difference between the object and its background must also be constant. For example, from Fig. 4 which pertains to a visibility level of 5, the brightness difference is 7.6 footlamberts when the contrast is 95 per cent. In other words, regardless of how the contrast is obtained, with either high or low reflectances, the footcandle level must be such as to produce a brightness difference of 7.6 footlamberts in order for the task to have a visibility level of 5. This, of course, means that low reflectances of object and background require high footcandle levels. The 95-per cent contrast may be obtained with background and object reflectances of 20 and 1 per cent, respectively. In this case 40 footcandles are required as compared with 10 footcandles when the respective reflectances are 80 and 4 per cent. Thus, Fig. 4 emphasizes the importance of including the reflectance of the object and its background when determining the footcandle level for any desired visibility level. In other words, how a specific value of contrast is obtained is just as important as the value of contrast itself.

As the contrast decreases, the brightness difference must be increased accordingly. For contrasts between 95 and 20 per cent, the brightness differ-

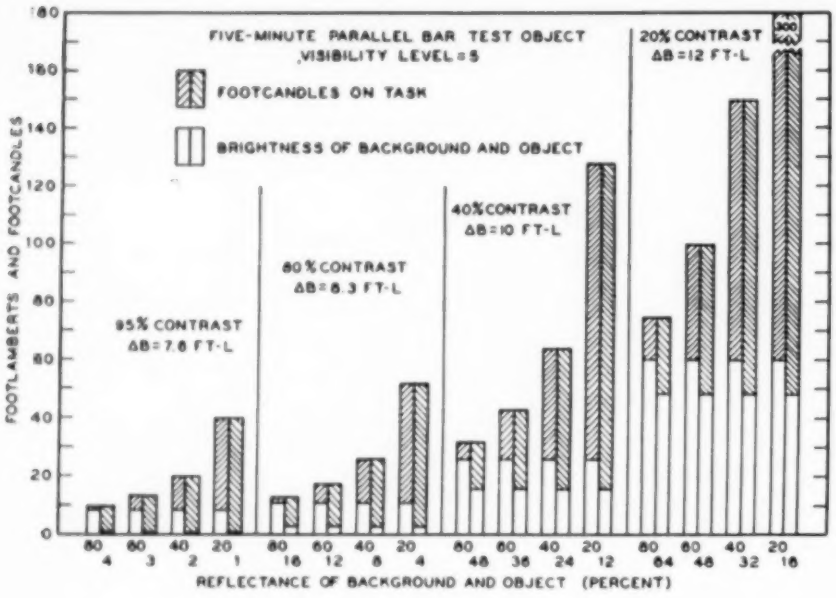

Figure 4. Footcandle, brightness, and brightness difference relationships for a five-minute parallel bar test object at a visibility level of 5 with contrasts of 20, 40, 80 and 95 per cent. Each contrast is obtained with four different combinations of background and object reflectances. To maintain the same visibility level, the brightness difference must be constant for each contrast, regardless of how the latter is obtained.

ences required for a visibility level of 5 range from 7.6 to 12 footlamberts. In comparison with other factors and criteria this is a relatively small variation. It may be possible to use a single value of brightness difference to obtain, on an approximate rule of thumb basis, the footcandles for any desired visibility level. Thus, a brightness difference of 10 footlamberts could be assumed for a visibility level of 5. This would result in 50 footcandles for a 95 per cent contrast (20 per cent background, 1 per cent object) and 250 footcandles for a 20 per cent contrast (20 per cent background, 16 per cent object). These footcandle levels would provide visibility levels of 4.6 and 5.2, respectively, as compared to the desired value of 5. These are not considered to be serious differences, because of the wide variations among individuals.

In Fig. 5 are illustrated graphically the relationships between brightness difference and visibility level for several values of contrast. The upper curve of each shaded area represents the brightness of the background and the lower curve represents

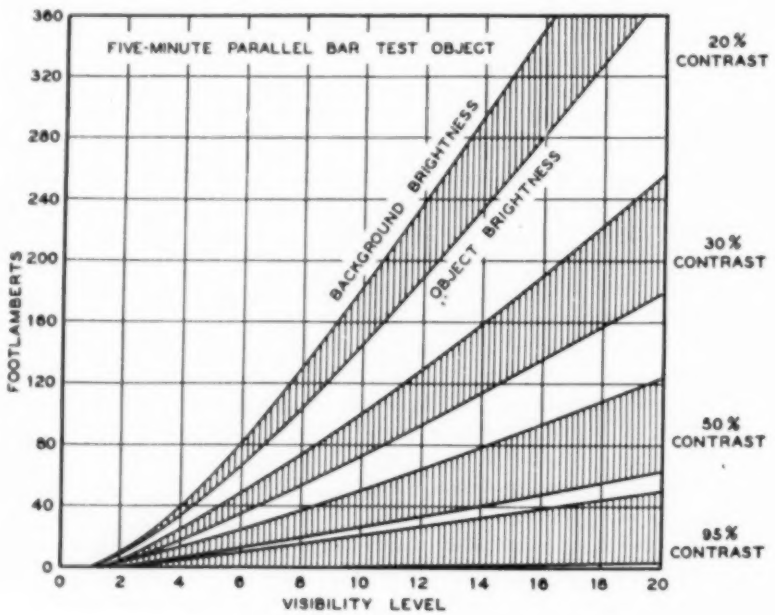

Figure 5. Graphical illustration of the relationships between brightness difference and visibility level for several values of contrast. The brightness difference required for any visibility level is represented by the vertical distance between the upper curve (background brightness) and lower curve (object brightness) of each shaded area.

the brightness of the object. If the object were the brighter, the designations would be reversed. The vertical distance between each pair of curves represents the brightness difference required for any given visibility level. For example, with a 5-minute parallel bar test object having a contrast of 50 per cent, a visibility level of 2 is obtained with a brightness difference of 1.6 footlamberts. However, a brightness difference of 62 footlamberts is required for a visibility level of 20 for the same object.

These curves also illustrate that relatively small brightness differences, and hence easily attainable brightnesses, are required for high contrast tasks, even to obtain high visibility levels. On the other hand, much higher brightnesses are required to obtain the necessary brightness difference when the contrast is low. However, even with low contrast tasks, the brightnesses required for moderate visibility levels are not excessive, even though the footcandle levels may be difficult to obtain especially with low reflectances. Nevertheless, such a difficulty should not be considered a serious obstacle to providing adequate means for seeing.

It appears that a brightness difference concept also can be applied to the appraisal of comfort and ability to see, when applied to the task and surroundings. In some earlier investigations[2] it has been shown that contrast sensitivity and ease of seeing are maximal when the brightness ratio between the task and its surround is unity. When the surround is brighter or less bright than the task, both contrast sensitivity and ease of seeing decrease. However, when the data were presented in terms of brightness ratio, the relationships were skewed, a surround to task ratio greater than unity (5/1) being less desirable than a corresponding ratio less than unity (1/5). When the brightness relationships are converted into differences rather than ratios, both contrast sensitivity and ease of seeing are indicated as decreasing approximately the same regardless of the direction of the brightness difference. The reasonableness of this can be illustrated by an example. If a task brightness is equal to 10 footlamberts, the surround brightnesses for 5/1 and 1/5 ratios would be 50 and 2 footlamberts, respectively. The corresponding brightness differences are 40 and 8 footlamberts. It seems obvious that the larger brightness difference should be expected to produce greater discomfort.

In the extensive investigations of the various factors which govern whether sources of brightness are comfortable or uncomfortable,[3] the same general concept can be applied, especially to large luminous areas such as usually are involved in typical lighting installations. A calculation of the relationship between source brightnesses at the borderline between comfort and discomfort and adaptation brightnesses ranging from 5 to 100 footlamberts indicates an approximately constant brightness difference for a 90 per cent comfort rating. The indicated values range from about 40 to 50 footlamberts. That is, a brightness difference of about 45 footlamberts between a visual task and sources of brightness should be expected to be comfortable for 90 per cent of the occupants of the area. For example, when the task brightness is 10 footlamberts, the source brightness should not exceed about 55 footlamberts; similarly, when the task brightness is 50 footlamberts, the maximal permissible source brightness is about 95 footlamberts. These values are for sources that may be viewed directly. Therefore, if sources are displaced from the line of vision, correspondingly higher source brightnesses and brightness differences will be tolerated. Similarly, larger brightness differences will be permitted for small area sources.

From the foregoing it is seen that the brightness difference concept affords an interesting approach to a better understanding of the benefits that can be received from higher levels of illumination. Greater emphasis is placed upon brightness. Appraisals can be made in terms of visibility and related directly to threshold observations. The application of brightness difference to ease of seeing and quality of lighting permits a coordinated analysis in terms of this basic and sensitive visual function. Such a concept ultimately may also have application to problems involving color differences.

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DISCUSSION

LELAND H. BROWN*: The authors of this paper have made a much greater contribution to illuminating engineering than they realize.

Scientists have found that any complicated problem can best be analyzed by resolving it into its elements and then seeing what happens if one or at most two of the elements are varied while all the others are held constant.

In illuminating engineering it has been traditional to say that the visibility of an object is dependent upon four factors: size, contrast, brightness, time.

The authors, however, have dared to break this tradition by pointing out that contrast is not a single element but a ratio involving several factors. However, while daring to question tradition, they have weakened their paper by pay-

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ing too much respect to contrast. So much so, that for the casual reader they have even defined the difference in brightness between the object and its background in terms of contrast and background brightness.

I wish they had come right out and said that the four basic factors that determine the visibility of an object are actually: object size, object brightness, background brightness and time for seeing.

These four factors are the only ones, and they are fundamental. True if either the object or background is not self luminous, then their respective brightnesses are equal to the product of their illumination and reflectance. But in the final analysis, object size, time, object brightness and background brightness are the four basic factors that determine the visibility of an object.

If one then keeps the size of the object and the time for seeing both constant, it becomes obvious that the visibility of an object will of necessity be dependent upon the brightness difference between the object and its background.

I am sure that the authors must have considered such a forthright approach and then decided that it might be too daring. I wish they had had the courage of their original convictions.

Their examples in the paper show very effectively how dependent visibility is upon this brightness difference. They also show how much more informative data are obtained when one works with brightness differences than when one uses the more obscure and confusing concept of contrasts.

It is hoped that not only will future researches be based on brightness differences, but that much of the past research data based on contrasts may be converted into the more basic and usable form of brightness differences.

LEONARD C. MEAD*: This paper is certainly interesting, especially with respect to its facile manipulation of the variables determining visual acuity and to the evolution of the concept of brightness difference as a determining variable. I wonder, though, if we do not already have enough, if not too many, of such variables. So often new ones are suggested which are simple derivatives of the old. When, as is usually the case, the new fail to replace the old, the vocabulary and ultimately the literature become cluttered and confused. It is my feeling that "brightness difference" may be such a variable.

Certainly, contrast alone is not adequate to serve the function the authors desire for "brightness difference" because high contrasts are possible when object brightness is sub threshold. Yet, the same is true of "brightness difference." Furthermore, when we are treating visibility and acuity in general we must consider the case of the transilluminated test object or background, in which case "brightness difference" and contrast become essentially the same since increases in illumination change both contrast and "brightness difference." In one instance "brightness difference" seems the same as contrast and in another it seems to suffer the same shortcoming.

I wonder, too, about the extent to which the experiment had to be performed. Once the concept of brightness difference was arrived at it would seem that its empirical basis could have been established by manipulation of the data obtained by Blackwell here, by Weston (for visual acuity test objects) in England, and by the classical data on visibility and acuity when transilluminated objects or backgrounds were used. Since it has been performed, however, it certainly serves as a desirable and valid check.

In the end I believe that I would vote for the retention of the old variable. Contrast seems adequate if threshold contrasts are specified along with threshold brightness of the test object under conditions of minimal contrast. We already have the term. It is being widely circulated, in Chapanis, Garner, and Morgan, in the Tufts Handbook, in the Vision Committee's Standards for Research on Visual Displays, etc. It is certainly no more difficult a computation than "brightness difference." "Brightness difference" can easily be derived from it where such a term better describes some visual function.

DOMINA EBERLE SPENCER*: Before we are tempted to interpret the Guth-Eastman-Rodgers paper as a basis for considering "brightness difference" as a fundamental visual concept, let us examine the situation more carefully. On the last page, the statement is made that "a brightness difference concept can also be applied to the appraisal of comfort and ability to see, when applied to the task and surroundings." The suggestion is made that "a brightness difference of about 45 footlamberts should be expected to be comfortable for 90 per cent of the occupants." If ΔB is a basic concept, it should have general applicability.

Let us go outdoors in the daytime: On a sunny day the brightness of a building may easily reach 1000 footlamberts. According to the suggested criterion, 1045 footlamberts is on the verge of being uncomfortable. Do you believe that a contrast of 4 per cent on a sunny day is intolerable to 10 per cent of the people?

Let us take another trip outdoors at night: Perhaps the sky has a brightness of 0.001 footlamberts. According to the ΔB criterion, a brightness of 45 footlamberts is all 90 per cent of the people can stand. Yet the moon is 20 times as bright as is allowed. And I am sure that more than 90 per cent of the people find moonlight delightful!

The difficulty is not that we need a new concept. We need rather to learn to use an old concept — "adaptation helios." This concept was based on one of the finest pieces of research that has ever come out of Nela Park — on the basic experimental work of Holladay, published 25 years ago. If Holladay's successors were to take data as he did, covering the range of values from starlight to sunlight, and would learn to utilize the modern interpretation of his work, they would find their new concept quite unnecessary.

S. K. GUTH, A. A. EASTMAN and R. C. RODGERS**: Perhaps it may be well to state that we do not consider ourselves as "discoverers" of brightness difference. It is not a new term or concept in visual research, but merely a little used one. It generally has been limited to studies of brightness discrimination. We, along with a few others, believe that it has a more general application and provides a better understanding of the effectiveness of light and lighting.

As Dr. Brown has so well emphasized, object and background brightnesses are fundamental factors. The relationship between them for any given adaptation level determines whether the object is visible or invisible. Perhaps we were conservative in not advocating the use of brightness difference in place of a derived value such as contrast. We do agree with him that basic factors should be absolute physical quantities. Nevertheless, there are times when relative brightness difference or contrast may be convenient for expressing fundamental relationships. It may be difficult for some persons to visualize brightness difference because of their long time usage of contrast. Furthermore,

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perhaps many people have tended to make the two terms synonymous. That is, when speaking of a high contrast test object, they actually think of a larger brightness difference than they do for a lower contrast object.

Dr. Mead's reluctance to use brightness difference is understandable. So much of the available data are presented in terms of contrast. However, we are sure that he recognizes the importance of such a factor and its application to suprathreshold seeing. The fact that brightness difference and contrast both change with transilluminated test objects or backgrounds should not be discouraging. Contrast still is relative brightness difference.

One of the primary purposes of our paper was to illustrate how suprathreshold visibility, as evaluated with the Luckiesh-Moss Visibility Meter, could be related to threshold observations. Thus, it was necessary to conduct an experiment of at least reasonable extent. It is obvious that a specific value of contrast can be obtained by a wide range of object and background reflectances (or brightnesses). The common denominator among these is that a constant brightness difference will provide a constant visibility level regardless of how the contrast is obtained.

Typical seeing situations involve specific tasks in which, for each, contrast is constant regardless of the footcandle level. It is not the variable that Dr. Mead says it is. Thus, the pertinent variables are the brightnesses of the object and its background. As the footcandle level is increased, these brightnesses and the differences between them increase. It seems entirely logical to use a variable which involves both brightnesses such as brightness difference rather than only the background brightness as is usually done.

In her discussion, Dr. Spencer tries to extend our general conclusions regarding comfortable brightness differences to outdoor conditions with sunlight and moonlight. We specifically stated that the 45 footlambert brightness difference held for adaptation brightnesses ranging from about 5 to 100 footlamberts. Extrapolation beyond the range of experimental data often leads to unwarranted conclusions, as she has so well illustrated. However, it might be well to point out that the building brightness of 1000 footlamberts in her example may be uncomfortable because of the extent of the bright area. Adding a relatively few footlamberts merely changes the degree of discomfort.

Another point which Dr. Spencer illustrates is the influence of size of source. Not only does she introduce high and low brightnesses, but also large and small luminous areas. As we have pointed out, larger brightness differences will be permitted for small area sources — and the moon certainly is one of these.

Our hope is that more consideration will be given to brightness difference as a basic factor in seeing. It seems to have broad possibilities and should result in a better understanding of how and why improved lighting provides better seeing.

Modular Lighting in Masonic Temple

Perimeter lighting is the theme of this recent installation in a Masonic Temple at Homestead, Pa. To insure a level installation in an old building, the luminaires were mounted on flexible hanger channel. The side lighting consists of two-lamp 8-foot module units using 75-watt T12 lamps and provides 25 footcandles on the seating area. Matching spotlight units, using 150-watt, PAR38 floods, highlight the Officers' stations. Over the center altar 100 footcandles are achieved by the use of four 4-foot modules with two 4-foot slimline lamps each and four 150-watt spots.

Installation was designed by A. G. Caplan, Duquesne Light Co., Pittsburgh, Pa. ***Photo courtesy Mitchell Manufacturing Co.***

Branch Banks

One of the most active phases of lighting design these days is in branch banks, new and remodeled. High ceilings, relatively large areas, and the trend to attractive intimate interior design, present a special challenge in their lighting solution.

Two-lamp recessed troffers and a single-lamp cove provide a maximum of 90 ft-c over the main banking area (below) in the Liberty Federal Savings and Loan Association, in Philadelphia, with an average illumination over 70 ft-c. A total of seventy-two 74-watt standard cool white T12 lamps, on 430 ma, are used in the troffers, while the cove contains eighteen 75-watt and two 54-watt T12 lamps. The banking area is 61 by 44 feet in area with ceiling height of 11 feet. Reflectances are: ceiling, 80 per cent; walls 50; floor 35; rug 9; and furniture 20 per cent. Architect on this installation was J. Sindoni; lighting engineer was G. T. Anderson Jr., Philadelphia Electric Co.

This suburban building and loan office, Lincoln Savings and Loan, Carnegie, Pa., inspirires customer confidence by attractive surroundings and architectural lighting. Three-lamp semi-recessed troffers, with plastic bottoms, give 30 ft-c downlight as well as ceiling illumination. Over the traffic aisle, a specially designed housing containing R40 floods is also semi-recessed and has a perforated exposed band allowing side light. An entire wall takes on a new appearance from the continuous row of cool white, 40-watt lamps, located one foot from the wood-paneled surface. These lamps are concealed behind an architectural beam in which there are four recessed downlights with narrow beam spread. These units add illumination on the small desks used by customers. Lincoln's portrait, the emblem of this organization, is highlighted by a silver bullet type housing using a 150-watt R40 spot. Installation was designed by C. B. Ross, Duquesne Light Co., Pittsburgh, Pa.

Bank on Good Lighting

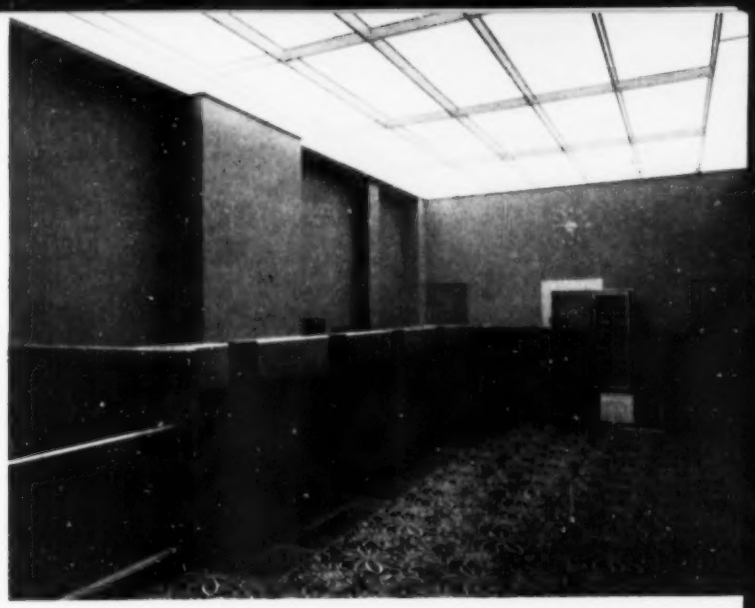

Photo courtesy of Luminous Ceilings Inc., Chicago, Illinois.

Cross baffle application of an acoustical ceiling (above) gives the Mutual Federal Savings and Loan Association of Washington, D. C., high level (50 ft-c) illumination, acoustical treatment, and combines with interior appointments to form a fresh modern interior. In remodeling, the 17-ft 8-inch ceiling was dropped to 14 ft by installation of the luminous element. A plaster ceiling around the perimeter of the room is furred level with the luminous ceiling and contains the air-conditioning diffusers, thus preserving the unity of the luminous area. Acoustical baffles are arranged in a modular pattern approximately 3 ft by 10 ft, acting as a giant louver beneath the ceiling, and lowering still further the apparent brightness. A 3-ft strip on all sides of the baffle area is flush luminous ceiling with T-track only. The 4-foot plenum is plaster painted flat white; no reflector strip necessary. Continuous rows of 8-ft channels use 2-lamp 40-watt ballast with lamps on single strip in tandem on 33-inch centers. High reflectance surfaces (light green wall, blonde furniture) keep all brightness ratios within a 10:1 limit. This attractive banking interior was designed by George W. Clark, architect, of Hoggson Bros. Inc., bank building specialists of New York City.

This bank, a branch of the Mellon National Bank, in the small city of Butler, Pa., receives 30 ft-c illumination in service from a newly-developed luminaire, inspired by this installation. These 4 by 4 ft square units, each containing six 40-watt T12 lamps, are recessed in the 13-ft acoustical ceiling, and spaced on 12-ft centers. Walls are painted a pastel rose, which helps to offset the lack of red in the standard cool white fluorescent lamps. Ceilings are white with 85 per cent reflectance, an important factor with a totally recessed installation. Data submitted by the West Penn Power Co., through A. G. Caplan, Pittsburgh Section Data Sheet Reporter.

Tests Aimed at Realistic Maintenance Factors

By R. L. OETTING
J. W. TUTTLE

WHEN illumination results do not agree with predicted values, the consumer rather logically takes the attitude of being oversold or inadequately served. Although most discrepancies are due to incomplete rather than incorrect data, all factors used in illumination calculations are being re-examined. Test facilities[1] have been developed to increase the coverage as well as the precision of utilization data and this study was undertaken to explore the possibility of providing more representative maintenance factors.

A test program was planned to

1. Measure the depreciation of systems representative of a majority of office and school installations, many stores, and the better quality industrial designs.
2. Separate the various factors contributing to illumination depreciation — lamp lumen depreciation, dirt on lamps, dirt on fixtures, room surface depreciation.
3. Determine if a correlation exists between the depreciation of lighting systems and the loss in reflectance or transmittance of "atmospheric indicators" due to dirt accumulation.

Test Procedures

Thirteen offices in the Engineering Building of the General Electric Company at Nela Park, Cleveland, were selected for test areas. Lighting systems varied from luminous indirect to totally direct. (See Table I.) Only fluorescent systems were included.

The following steps were taken to ready each office for the test. Those scheduled for washing or painting during the year were refurbished immediately. Notices were posted with the operating department and in the offices to remove them from the normal maintenance program and to avoid any unusual usage of the systems. (See Fig. 1.) All fixtures were washed *thoroughly*.

To minimize the interference of lamp failures, all fixtures were equipped with new, *seasoned* lamps. A photometer (Fig. 2) was developed to measure the relative output of each lamp so that lamp depreciation could be separated from that due to dirt. By means of a variable autotransformer, system voltage was maintained at 118 volts during all test periods. Normal operating temperatures were also maintained as closely as possible. For instance, each enclosed unit was opened just prior to making lamp photometry measurements.

The reflectance of room surfaces was measured at representative and designated spots. A Baumgartner Reflectometer[2] was used. The reflectance and, where applicable, the transmittance of atmospheric indicators were measured. These indicators were 4-inch by 4-inch panels of white synthetic enamel on steel, anodized aluminum, smooth-surfaced diffuse acrylic plastic, sandblasted clear acrylic plastic, and sandblasted diffuse glass. Three sets of these panels were supported on a rod frame from the picture molding in each test office. One set was horizontal, one vertical, and one in a 45-degree sloping position. (See Fig. 3.) They were installed at approximately fixture height and in as similar a location in each office as possible.

The average illumination of each system at desk level was determined from measurements at the center of test areas not exceeding 3 ft by 3 ft. Average illumination was also obtained by the I.E.S. survey method. Measurements were made with a cosine- and color-corrected precision illumination meter[3] under stabilized and recorded conditions of temperature and voltage.

Illumination, reflectance and transmittance measurements were made at the end of each of the first five months (at which time preliminary results were reported at the 1952 National Technical Conference in Chicago). Similar measurements were also made at the end of the eighth and twelfth months. Initial and final illumination surveys employed both the I.E.S. method and the total area method. Intermediate surveys employed only the I.E.S. method.

At the end of the twelfth month, atmospheric indicators were measured; lamps were photometered; and illumination surveys were made with the I.E.S. method in this order:

a) with the fixture intact and with accumulated dirt,
b) with louvers or enclosures, where employed, removed,
c) with louvers or enclosures, where employed, removed and with the lamps thoroughly washed.

Based on a paper presented at the National Technical Conference of the Illuminating Engineering Society, September 8-13, 1952, Chicago, Illinois. Additional data covering a full year of testing are now included. Authors: General Electric Company, Lamp Division, Cleveland, Ohio.

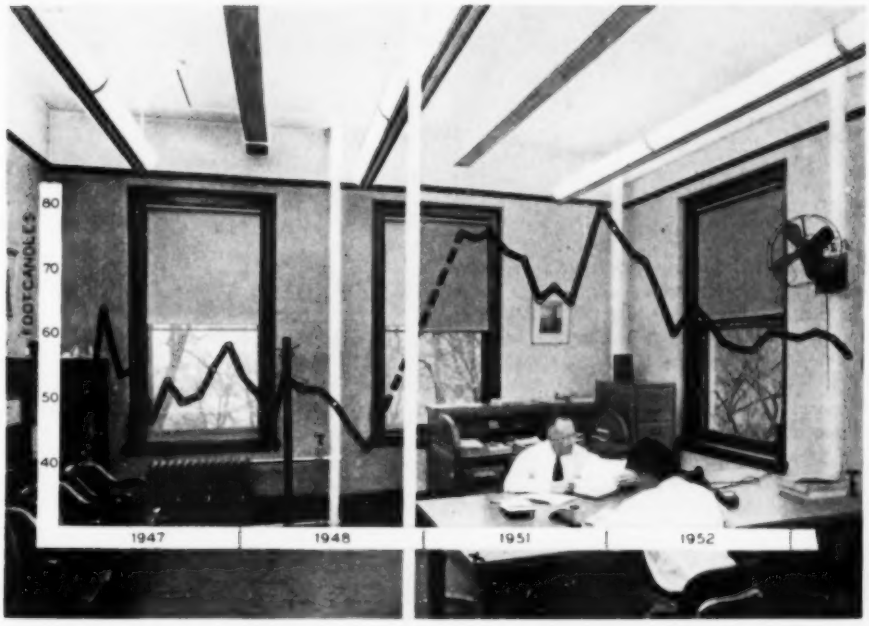

Figure 1. A casual illumination depreciation check in this office, in part, suggested a comprehensive survey of it and twelve other offices. Monthly readings were taken on the corner of the table. The survey was interrupted in 1949 when a power shortage required a reduction in all lighting loads. Meantime the room was repainted, cool white lamps replaced daylight and a more thorough maintenance program was adopted. The peak value in 1951 indicates the start of the depreciation test period. After 12 years of use, the installation is providing at least 30 per cent more light than formerly, due to higher reflectance walls, increased lamp efficiency and better maintenance.

TABLE I.—Data on Test Rooms and Lighting Systems.

		Height			Lamps			Units			
Office	Dimension	Ceiling	Fixture[1]	Index	Size	Starting	No. per Unit	No.	Shielding[2]	Distribution[3]	Material and Description
1	14′ 8″ x 17′ 9″	11′ 7″	10′ 6″	H	85WT17	PH	2	6	40° x 40°	48 52 DI	Anodized aluminum sides Baffle type louvers
2	17′ 6″ x 17′ 8″	11′ 9″	10′ 2″	G	85WT17	PH	2	9	90° x 90°	85 15 SI	Enamelled glass sides[5]
3	14′ 6″ x 17′ 9″	11′ 8″	10′ 6″	H	40WT17	IS	2	12	40° x 5°	42 58 DI	Anodized aluminum sides No louvers
4[4]	17′ 8″ x 20′	9′ 10″	10′ 3″	H	96T12 48T12	IS IS	3 3	9 2	42° x 22°	0 100 D	Anodized aluminum troffer Vinyl plastic ceiling
5	14′ 10″ x 17′ 7″	11′ 8″	11′ 2″	H	96T12	IS	2	6	35° x 25°	50 50 DI	Polystyrene sides, synthetic lacquer enamel
6	14′ 6″ x 17′ 10″	11′ 7″	10′ 10″	H	72T12	IS	4 2	4 2	45° x 45° 45° x 45°	40 60 DI 40 60 DI	Synthetic lacquer enamel Small egg-crate louvers
7	14′ 7″ x 17′ 10″	11′ 8″	10′ 4″	H	96T12	IS	4	4	45° x 30°	52 48 DI	Polystyrene sides, cast egg-crate polystyrene louvers
8	14′ 6″ x 17′ 9″	11′ 8″	10′ 10″	H	40WT12	RS[6]	4	6	35° x 25°	51 49 DI	Synthetic lacquer enamel Egg-crate louvers
9	14′ 5″ x 14′ 10″	11′ 9″	11′ 4″	H	40WT12	PH	2	9	90° x 90°	21 79 SD	Prismatic glass enclosed[5]
10	6′ 5″ x 17′ 8″	11′ 8″	10′ 6″	J	72T12 48T12	IS IS	2 2	4 1	90° x 90° 90° x 90°	19 81 SD 19 81 SD	Polystyrene and acrylic plastic enclosed[5]
11	14′ 6″ x 17′ 8″	11′ 8″	10′ 5″	H	96T12	IS	4	4	45° x 45°	58 42 DI	Synthetic lacquer enamel Baffle type louvers with two longitudinal blades
12	11′ 4″ x 18′	10′ 1″	10′ 8″	I	40WT17	IS	1	12	45° x 25°	0 100 D	Anodized aluminum troffers Baffle type louvers
13	7′ x 17′ 9″	11′ 8″	10′ 6″	J	96T12	IS	2	4	35° x 45°	52 48 DI	Synthetic lacquer enamel Baffle type louvers

[1]Floor to light center of unit.
[2]Crosswise by lengthwise.
[3]Per cent light upward and downward; classifications: I—indirect, SI—semi-indirect, DI—direct-indirect, SD—semi-direct, D—direct.
[4]A combination of 2 lamp troffers and luminous ceiling elements lighted by a third lamp on top of troffer channels.
[5]Metal parts of unit are synthetic lacquer enamel.
[6]New rapid start lamps and ballasts.

Figure 2. Far left: Photometer for measuring relative output of test lamps. It contains two matched color-corrected cells and accommodates both T12 and T17's. The photograph is a modification of one developed by G. R. Baumgartner and described in ILLUMINATING ENGINEERING, November 1944. Left center: Microammeter used in connection with photometer and reflectometer. Right center: Source of diffuse light for transmission measurements of atmospheric indicators. Top frame is fitted with special jig that receives test plate holders. Holder parts (resting against supporting legs of sphere) accurately center test plates, prevent loss of dust by contact with reflectormeter. Right: Baumgartner reflectometer with special frame for bracing instrument during measurements of ceiling reflectance.

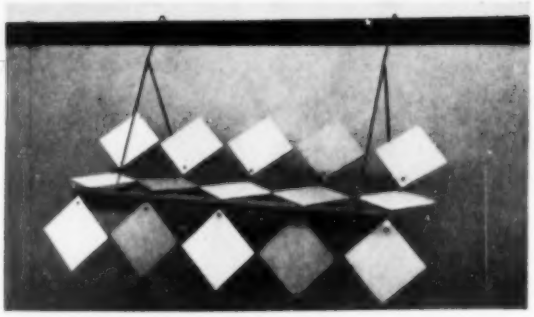

Figure 3. Each atmospheric indicator is 4" x 4". Each set consists of panels of (left to right) white synthetic enamel on steel, anodized aluminum, smooth diffuse acrylic plastic, sandblasted clear acrylic plastic, and sandblasted Alba-lite glass. Three sets are supported on a rod frame from the picture molding in each test office.

d) with louvers or enclosures, where employed, removed and with the lamps and remaining portions of the fixtures thoroughly washed.

e) with the fixtures intact and with all components thoroughly washed.

Results

The problem of maintaining a constant ambient temperature was fairly well met even though the test period lasted a full year and ventilation or the adjustment of steam radiators were the only methods of temperature control. Windows were opened at times to keep offices from reaching excessive temperatures, but were generally closed during test periods. The light output of fluorescent lamps is, of course, affected by drafts as well as by the ambient temperature. The maximum range of temperature was from 76° to 92°; the average was 82.7°. Some 93 per cent of the tests were conducted at temperatures within 5° of this value. For initial and final test conditions, at which times the most important data were obtained, the average temperature was 83.5° and 98 per cent of the tests were made at temperatures within 5° of the average.

Illumination maintenance results are shown in Fig. 4 for the thirteen offices studied. Data for office No. 4 were not included in the determination of average maintenance values nor in further

TABLE II.—Summary of Maintenance Values After Twelve Months.

	Maintenance Values[1]							
Office	M Total	M_{L}[2] Lamp Lumens	M_{d} Total Dirt	M_{ld} Lamp Dirt	M_{r} Refl. Dirt	M_{lv} Louver Dirt	M_{fd} Fixture Dirt	M_{rs} Room Surfaces
1	.71	.84	.85	.97	.99	.96	.92	.92
2	.68	.84	.81	.93	.95	—	.88	.92
3	.75	.88	.85	.96	.98	—	.94	.99
4	.78	.88	.88	—	—	—	.88[3]	1.00
5	.78	.88	.89	.96	.99	1.02	.97	.92
6	.75	.88	.85	.92	.99	.96	.88	.97
7	.76	.88	.86	.95	.97	.96	.90	.96
8	.78	.88	.89	.97	.96	.97	.90	.99
9	.78	.88	.89	1.00	.94	.91[4]	.87	1.02
10	.75	.88	.85	.98	.94	.95[4]	.88	.97
11	.77	.88	.88	.97	.99	1.00	.94	.92
12	.81	.88	.92	.97	.99	1.00	.96	.96
13	.81	.88	.92	.97	1.00	1.00	.96	.96
Avg.[5]	.76	.87	.87	.96	.97	.98	.92	.95

[1]Maintenance denotes per cent of initial.

[2]Standardized lamp-lumen values for estimated hours of lamp use.

[3]This value is for the combination of troffers and luminous ceiling elements. Individual values are .89 for the troffers and .79 for the ceiling elements.

[4]This unit is enclosed, not louvered.

[5]Data for office No. 4 are not included.

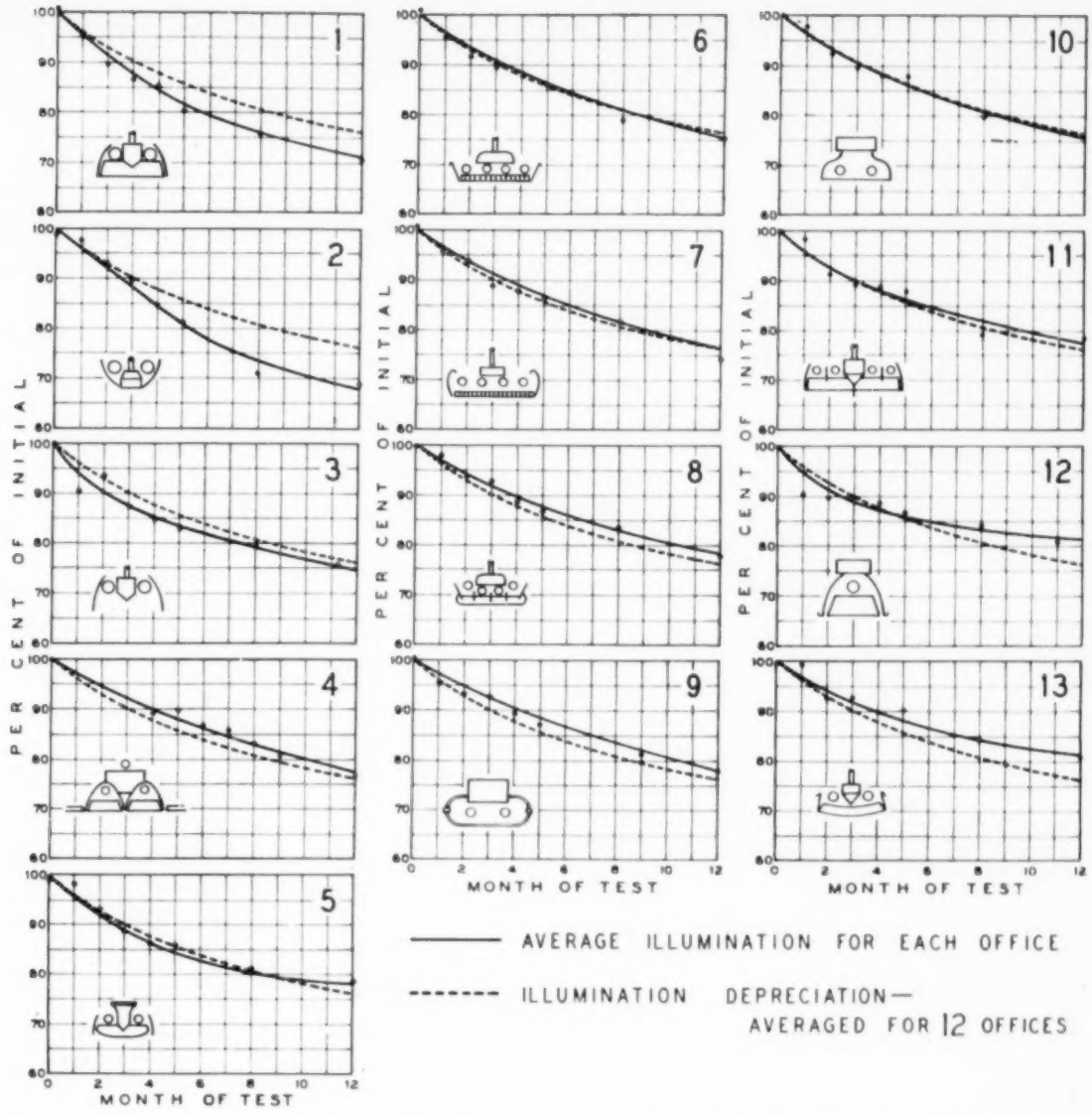

Figure 4. The overall depreciation or maintenance of each lighting system is compered with the average for all offices except #4. Schematic cross-sections show the arrangements of lamps and fixture components, described in Table I.

analyses of data. The initial survey of this office has been reported previously.[4] It was made four months prior to the start of this more comprehensive study and the test period did not coincide with that for the other offices.

Table II represents a summary of maintenance values. It is emphasized that results are presented as *maintenance* values and not as depreciation data. The *product* of individual maintenance values yields the total or overall result which is associated with the value customarily identified as *maintenance factor*.

Standardized lamp-lumens for the estimated hours of use are shown in Table II and were used in calculations of other factors. In spite of many precautions, test results were not sufficiently consistent with standardized data to warrant their use. Although standardized data did not reflect the variations due to differences among lamps and in the use of the test offices, nor those due to changes in ballast performance, they were more accurate than the results obtained under field-test conditions. Maintenance values shown in Table II were obtained for each office as follows:

TABLE III.—Correlation Between Maintenance of Lighting Systems and Maintenance of Certain Indicators.

Office	(m) Values[1]							(m_d) Values[2]						
	Month of Test							Month of Test						
	1	2	3	4	5	8	12	1	2	3	4	5	8	12
1	.97	.93	—	.90	.88	.85	.88	1.00	1.00	.99	.97	.97	.96	.99
2	1.01	.98	.97	.93	.92	.88	.90	1.01	1.01	1.01	.98	.98	.94	.96
3	.96	—	.93	.92	—	.90	.93	.99	.98	.98	.97	.98	1.00	1.04
5	1.00	.99	.98	.97	.98	1.00	1.08	1.00	1.01	.99	1.00	.99	1.02	1.10
6	1.03	1.01	1.00	1.00	1.01	1.04	1.06	1.02	1.02	1.02	1.02	1.02	1.05	1.06
7	.98	.96	.95	.94	.94	.94	.95	1.01	1.02	1.02	1.01	1.00	1.05	1.05
8	1.00	1.00	—	.97	.97	.99	1.03	1.03	1.02	1.02	1.02	1.01	1.02	1.09
9	1.03	1.02	—	1.00	1.00	1.02	1.07	1.03	1.03	1.03	1.02	1.01	1.06	1.09
10	1.01	.99	—	.97	.97	.95	.96	1.02	1.03	1.01	1.01	1.00	1.00	1.00
11	1.00	.98	—	.95	.94	.96	.98	1.01	1.01	.99	.99	.98	1.01	1.05
12	.96	.93	.92	.93	—	.94	1.04	1.00	.98	.98	1.00	1.00	1.05	1.12
13	1.00	.98	.98	.96	.96	.94	.96	1.01	1.02	1.01	1.00	1.01	1.01	1.05
Avg.	1.00	.98	.96	.95	.96	.95	.96	1.01	1.01	1.00	1.00	1.00	1.01	1.05

[1]Ratio of M to m_i for diffuse glass and diffuse plastic indicators in horizontal position.
[2]Ratio of M_d to m_i for diffuse glass and diffuse plastic indicators in 45° sloping position.

(1) $$M = S_a/S_o$$

where M = Maintenance of the system due to all factors of depreciation.

S_a = Illumination at end of test with fixtures intact and with accumulated dirt.

S_o = Illumination initially.

(2) $$M_u = P_e/P_o$$

where M_u = Lumen maintenance of the lamps (Values were obtained with this equation and from standardized lamp-lumen maintenance data).

P_o = Relative output of lamps initially.

P_e = Relative output of lamps at end of test.

(3) $$M_d = M/M_u$$

where M_d = Maintenance of the system due to all dirt accumulation (and surface deterioration) factors.

(4A) $$M_w = S_b/S_c$$

or

(4B) $$M_w = S_a/S_c$$

where M_w = Maintenance of the system due to dirt on the lamps.

S_b = Illumination at end of test with louvers and enclosures, where employed, removed and with accumulated dirt. (For fixtures without louvers or enclosures, the factor S_a is used in equation 4B.)

S_c = Illumination at end of test with louvers and enclosures, where employed, removed and with lamps washed. (This survey was also made for fixtures without louvers or enclosures.)

(5A) $$M_x = S_c/S_d$$

or

(5B) $$M_x = S_c/S_e$$

where M_x = Maintenance of the system due to dirt on the fixed or attached portions of the fixtures. (Side panels in place unless part of the louver assembly.)

S_d = Illumination at end of test with louvers and enclosures, where employed, removed and with lamps and remaining portions of the fixtures washed. (Equation 5B applies for fixtures without louvers or enclosures.)

S_e = Illumination at end of test with fixtures intact and all components washed.

(6) $$M_y = S_a S_d / S_c S_b$$

where M_y = Maintenance of the system due to dirt on the louvers or enclosures of the fixture. (For fixtures without louvers or enclosures, the factor M_x indicates maintenance of the system due to dirt on the fixture.)

(7) $$M_{fd} = M_w \times M_x \times M_y$$

where M_{fd} = Maintenance of the system due to dirt on the lamps and fixture components.

(8) $$M_z = M_d/M_{fd}$$

where M_z = Maintenance of the system due to dirt on or the deterioration of room surfaces. (Permanent deterioration of fixture surfaces would be reflected in this factor, too.)

Maintenance values (m_i) for the five types and three positions of atmospheric indicators were calculated in terms of per cent of initial reflectance

and, where applicable, transmittance. These values were compared with those of M and M_d for each office. The best correlations (r and r_d) were obtained with transmittance measurements of the diffuse glass and diffuse plastic indicators. These two materials maintained so nearly identically that their values were averaged and applied as a single factor.

Correlation ratios are shown in Table III. On the *average*, the maintenance of the horizontal indicators was about the same as the M or overall maintenance values of the associated lighting system. The indicators in the 45° position matched the M_d values even more closely. On the basis of this near-unity correlation and with the assumption that differences in the maintenance values of the 45° indicators were proportional to the variations in atmospheric conditions, system maintenance values were adjusted to a common "average" atmospheric condition as follows:

$$M'_d = M_d\,(m_a/m_i) \tag{9}$$

where m_a = Average of the m_i values and
where the prime values have the same definitions as previously but apply for a common, average atmospheric condition.

$$M' = M'_d \times M_{ll} \tag{10}$$

$$M'_w = M_w\,(m_a/m_i)^{1/4} \tag{11}$$

$$M'_x = M_x\,(m_a/m_i)^{1/4} \tag{12}$$

$$M'_y = M_y\,(m_a/m_i)^{1/4} \tag{13}$$

$$M'_z = M_z\,(m_a/m_i)^{1/4} \tag{14}$$

$$M'_{fd} = M'_d/M'_z \tag{15}$$

Considering the overall adjustment ratio m_a/m_i as the product of four equally-weighted adjustments in M_w, M_x, M_y and M_z, the individual adjustments were then made in proportion to the fourth root of the ratio. The value of M'_{fd} was determined as the ratio of M'_d to M'_z rather than as the product of M'_w, M'_x, and M'_y to minimize errors due to rounding-off the component values. The maintenance values obtained for average atmospheric conditions are summarized in Table IV. Fixtures are grouped according to M'_{fd} values or their susceptibility to dirt depreciation in Fig. 5.

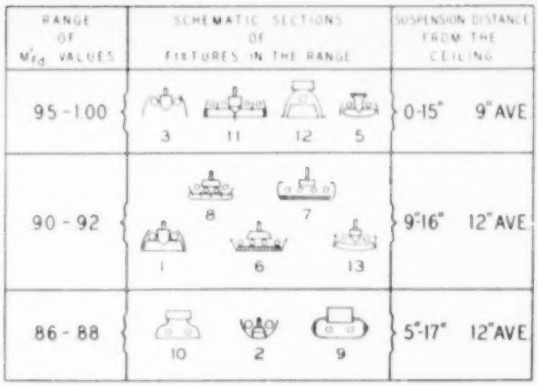

Figure 5. Fixture types have been grouped according to their M_{fd} values under the average atmospheric conditions of this test. A seeming correlation between maintenance values and suspension distance from the ceiling may be coincidental but is recorded for future consideration.

Analyses of Results

The accuracy of field survey data such as obtained in this study is always open to question. To obtain accuracies within one per cent, lamp-standardization laboratories resort to complete air conditioning of test rooms, the use of large integrating spheres, and the use of precision instruments which are calibrated frequently. A goal of two per cent is common for the more precise fixture laboratories and 10 per cent is frequently held as good for field results.

Since the experimental lamp-lumen maintenance

TABLE IV.—Summary of Maintenance Values Adjusted to Average Atmospheric Conditions After Twelve Months.

		Maintenance Values						
Office	m_a/m_i Atmosph. Ratio	M'_d Total Dirt	M' Total	M'_w Lamp Dirt	M'_x Refl. Dirt	M'_y Louver Dirt	M'_z Room Surfaces	M'_{fd} Fixture Dirt
1	.96	.82	.69	.96	.98	.95	.91	.90
2	.99	.80	.67	.93	.95	—	.92	.87
3	1.01	.86	.76	.96	.98	—	.90	.95
5	1.03	.92	.81	.97	1.00	1.03	.92	1.00
6	1.04	.88	.77	.93	1.00	.97	.98	.90
7	1.01	.87	.77	.95	.97	.98	.96	.91
8	1.01	.90	.79	.97	.96	.97	1.00	.90
9	1.01	.90	.79	1.00	.94	.93[1]	1.02	.88
10	.98	.83	.73	.97	.94	.96[1]	.96	.86
11	.99	.87	.76	.97	.99	1.00	.92	.95
12	1.01	.93	.82	.98	1.00	1.01	.97	.96
13	.94	.86	.76	.95	.98	.98	.93	.92
Avg.	1.00	.87	.76	.96	.97	.98	.95	.92

[1]This unit is enclosed, not louvered.

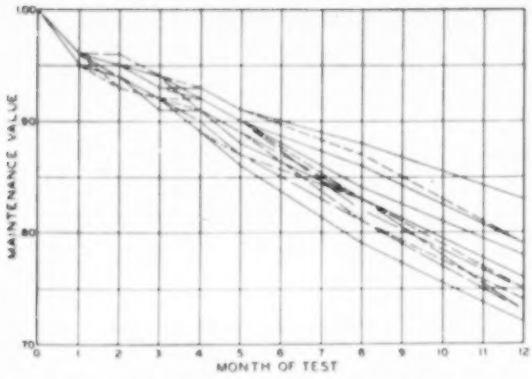

Figure 6. Transmittance of the horizontal diffuse glass and diffuse plastic indicators in each office were averaged and plotted as m_i in per cent of the initial value. With but few exceptions, the relative positions of the individual curves remain about the same during the entire period of the test.

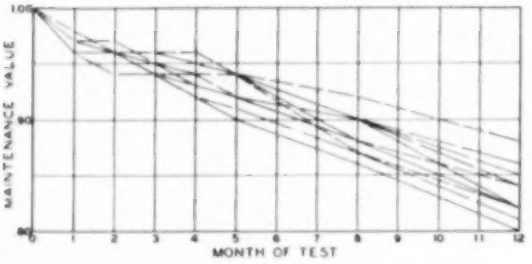

Figure 7. The m_i values for the 45° diffuse glass and plastic indicators in each test office.

results averaged five per cent higher than standardized data, they were rejected. Individual room values were as much as 9 per cent higher than standardized; none was lower. The purpose of field photometry, of course, was to determine individual lamp performance in the test fixtures and under test conditions. Results were not sufficiently consistent with standardized data, however, to be acceptable. This was in spite of refinements over previous techniques and careful analyses of results to locate the sources of error. Most other efforts to photometer lamps outside of properly equipped and controlled laboratories have also ended in unreliable results. Lamp-photometry experts emphatically discourage all such attempts. The techniques remaining for the field engineers are to have the lamps photometered in a qualified laboratory or to measure time of use and apply standardized lamp-lumen maintenance factors. The best compromise for reasonable effort and accuracy is to photometer the lamps in a laboratory initially and to apply standardized lumen-maintenance factors on the basis of accurately measured burning hours.

The eight maintenance values of 1.00 or more in Table II (there are ten in Table IV) give evidence of inaccuracies among the test data. In a few instances, they result from "rounding-off" component data. It should be noted that they occur only in those categories which consistently show very high maintenance values — where errors of only a few per cent are likely to be detected. A look at the design of the fixtures involved is reassuring. In Table II, the M_u value of 1.00 occurs for an enclosed unit; the M_x value of 1.00 is accompanied by five values of .99 for the units most similar in design; and the three M_y values of 1.00 are for "baffle-type" louvers. The M_y value of 1.02 for office No. 5 is the most obvious test-data error; the louver, however, is of the simple baffle type and of only 25° lengthwise shielding. The error is not likely to be more than 3 to 4 per cent. Similar errors may be represented in other data which are not subject to such close scrutiny. The use of high-precision, field-type instruments, frequent calibration and carefully conducted surveys has probably resulted in illumination data of better than five per cent accuracy.

Of the ten values in Table IV which are 1.00 or more, five correspond with factors in Table II which were also high. Adjusting to average atmospheric conditions raised five values to 1.00 or more and dropped two that had been. The percentages involved in these adjustments can be seen either as the m_a/m_i ratio in Table IV or as the deviation-from-average values of m_i (45°) in Table V. The latter showed the adjustments to be well within the accuracy expected of field tests and close to the estimated accuracy of *individual* illumination surveys. A pertinent question then was: Would adjustments of maintenance values in the ratio of m_a to m_i be significant?

Several considerations supported the propriety of making the adjustments. Individual maintenance data were compared graphically with the associated average data to eliminate data points in obvious error. For instance, monthly m_i values for the indicators were plotted and compared with the average for all the offices. Points which were incon-

TABLE V.—Maximum Deviations of Individual Values from Average for Several Maintenance Quantities.

Value	Month		
	4	8	12
	Per Cent Deviation from Average		
m_i (Horiz.)	+1·3	+4·7	+8·7
m_i (45°)	+2·2	+3·3	+6·4
M_u	+2·5	+5·9	+8·12
M_x	+2·3	+4·7	+6·8

sistent with the trends of the individual and average curves were noted and, if initial values, were modified. In this way, undue weighting of the initial test data was avoided. Similar adjustments in the twelfth-month indicator maintenance values might also have been made. Because none of the adjustments would have changed the grouping of the units in Fig. 5, twelfth-month values were not changed and the actual data relationships were preserved in Figs. 6 and 7. These show the individual room indicator trends. The tendency of the maintenance values to remain in consistent relationship, one to another, helped justify making the atmospheric adjustments in the ratio of m_a/m_i.

After one year, the highest indicator maintenance value is 110 per cent of the lowest which might suggest a ten per cent variation in atmospheric conditions. However, *depreciation* values are more indicative of the amount of dirt in the atmosphere and, on this basis, the maximum depreciation was 167 per cent of the minimum.

The building in which these tests were conducted is not closely associated with a factory but is located on the brow of a hill overlooking concentrated industrial areas. The direction of the prevailing wind is across these factories toward the building. No positive correlation between the exposure of the offices to this wind direction and the indicator maintenance values was discovered. Further tests are needed to ascertain how closely the conditions in the offices are representative of those in all offices, schools, stores and industrial plants.

The values of r_d were nearly unity throughout the first eight months. (See Table III.) The increases in the twelfth month caused a thorough examination of instruments and data. No experimental errors were discovered. Next the theory that transmitting materials show exponential losses of transmittance due to dirt accumulation was considered.[5] While system maintenance quantities continued to follow established exponential functions, indicator maintenance did not. Average trends for the horizontal and 45° indicators are plotted in Fig. 8. The expected exponential characteristics were in evidence through the first four or five months. Eighth-month data of themselves did not seem to depart appreciably but, in combination with the twelfth-month values, they developed a drop in the maintenance curves. These unexpected results were not interpreted as discrediting the value of the indicators nor the theory that they maintain exponentially over a longer period of time. The results may just as well establish that these indicators are reliable and respond to changing and differing dirt conditions in spite of the fact that the M_d values did not reflect as marked a shift in maintenance.

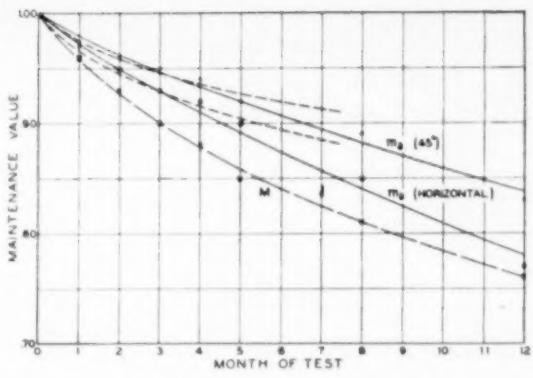

Figure 8. Data for curve *M* represent the average of the total maintenance values for all twelve lighting systems. It is clearly exponential in form. The dashed curves, fitted to average indicator maintenance (m_a) for the first five months, show similar characteristics. Later data altered these trends appreciably and final estimates of indicator maintenance functions are shown by the solid-line curves. Over the test period of one year, indicator maintenance data approximated linear functions with slopes of about 2 per cent per month for the horizontal position and 1.5 per cent per month for the 45°.

Results obtained for other indicator materials and positions and for room surface maintenance were not consistent enough to be considered. Too limited a sampling of room surfaces coupled with slight depreciation and the difficulty of reflectometer manipulation against walls and ceilings may account for the inconsistencies among the room measurements. Transferring the vertical indicators to the reflectometer in the laboratory undoubtedly caused a variable loss of dirt on these samples. A high degree of consistency was indicated for the laboratory reflectometer measurements, however. Reference samples were used for frequent comparison during the test period. The diffuse glass and plastic samples which were washed after the test averaged 98.6 per cent of initial transmittance. Since the plastic averaged 99.1 and the glass 98.0, the difference is taken as indicating instrumentation accuracy rather than any deterioration of the materials. An accuracy of better than five per cent is indicated.

In contrast to the apparent accuracy of data in this study are the results of typical "before and after" surveys as represented in Table VI. These data were obtained when the offices were prepared for testing. All fixtures were washed and relamped while some of the walls and ceilings were painted or washed. Although some installations were more recent than others, most had been in service for more than a year and all were operating under uniform conditions of maintenance. The increases

TABLE VI.—Illumination Before and After Initial Maintenance.

	Per Cent Reflectance				Illumination—Footcandles		
	Before		After				
Office	Walls	Ceiling	Walls	Ceiling	Before	After	Per Cent Increase
1	26.36	67.82	49.52	89.90	62.8	79.9	27.2
2	60.64	86.89	Same as before*		63.2	80.8	27.8
3	19.29	74.80	49.52	89.90	70.2	88.8	26.5
5	28.36	84.86	Same as before*		64.4	78.8	22.4
6	20.32	78.80	29.34	80	62.0	69.6	12.3
7	46.57	74.83	56.60	82.86	81.7	121.9	49.0
8	42.44	84.87	Same as before*		86.0	90.3	5.0
9	23.30	70.76	46.48	81.84	46.0	74.2	61.3
10	59.70	86	Same as before*		64.6	75.0	16.1
11	43.54	84.88	Same as before*		84.5	88.2	4.2
12	49.60	71.77**	Same as before*		49.1	68.4	39.3
13	52.59	72.76	Same as before*		57.6	70.0	21.3

*Offices 2, 5, 8, 10, 11, 12, and 13 were not washed or repainted.
**Acoustical tile.

in illumination ranged from 4.2 to 61.3 per cent. This wide spread emphasizes the impracticability of establishing realistic maintenance factors upon the results of casual before and after surveys. More thorough control or at least knowledge of conditions is needed.

This study of lighting maintenance was predicated on the need for careful measurements and for the control of as many variables as possible. All in all, the results seem realistic. The diffuse glass and plastic indicators gave more consistent and more nearly direct correlation results than hoped for. There is promise that transmitting indicators of 50-60 per cent transmittance in horizontal or 45° positions will, in 30 to 60 days, give a fairly reliable index of atmospheric conditions and lighting maintenance. Consolidation of individual test results will yield data broadly representative

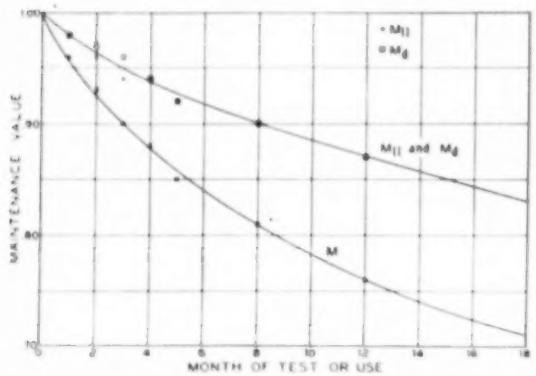

Figure 9. The average curve of total maintenance values (M) of all twelve systems is repeated here from Fig. 8. It is extrapolated for an additional six months. Average lamp-lumen (M_{ll}) and total dirt (M_d) maintenance curves are identical under the conditions of this test. The degrees to which individual rooms departed from average are shown in Table V.

of the different types of systems, areas, activities and geographical locations encountered in general lighting practice. Probable deviations from average conditions could also be predicted.

Fig. 9 is a step in the direction of developing average but realistic maintenance data. Although the use of more specific information, such as contained in Fig. 4 and Table IV, is recommended, it will not always be available nor properly employed. Maximum and minimum maintenance values for individual systems are listed in Table V in per cent of the averages shown in Fig. 9.

For the dirt conditions, lamps and fixtures of this test, lamp-lumen and dirt depreciations caused about equal illumination losses. Washing fixtures at intervals that are shorter than lamp life would make lamp-lumen maintenance the more important quantity in overall maintenance. If the washing were done annually, the maintenance factor component due to dirt would be about the mean value of M_d in Fig. 9. That due to lamp depreciation would continue to drop the longer the lamps were left in service. The practical way to minimize losses due to dirt is to wash fixtures. Certain improvements in washing techniques either encountered or developed during this test are summarized in Fig. 10. Reference to Table IV will show, for each fixture type, just where maintenance efforts should be placed—on washing lamps, reflectors, louvers or enclosures. To minimize losses due to lamp depreciation, lamps with high lumen maintenance must be used and simplified, group-replacement of lamps should be adopted. The frequency of lamp replacement as well as washing must be determined from an analysis of the costs and the benefits which are peculiar to each installation.

These tests were aimed at providing data for more realistic maintenance factors. They have established a sound, partial foundation. The base is not complete. Varied as atmospheric conditions were, further investigations of this factor are necessary. Varied as the fixture types were, more comprehensive samplings of basic types are needed. For instance, the exploration of variations in trofer types alone would constitute a full study.

These tests have also outlined a workable procedure for maintenance studies. They indicate how further tests may be simplified but also highlight areas in which the greatest care and control should be exercised. In the direction of simplification, the I.E.S. survey method was found to be practicable. It yielded results on the average that were 6 per cent higher than the area survey method, but the correlation did not shift with depreciation of the systems. Although all measurements in such studies warrant careful attention, those relating to lamp-

Figure 10. The maintenance techniques presented were developed both coincidentally with the test and in consultation with M. E. Mitchell, Mitchell Maintenance Company, Muncie, Indiana. A—When cleaning the inside of a reflector, two sponges—one a wash and the other a rinse—will often save time if the fixture is rigidly attached to the ceiling. A separate bucket and single sponge is best used on the top of the channel where large amounts of dirt will accumulate. B—The cleaning of the area around the lampholders is aided by the use of a 2" paintbrush. The wash solution is first brushed on, then the rinse, and the ends are allowed to drip dry. C—Operator grasps wash sponge in left hand, braces lamp on knee and, starting at upper end of lamp, moves to bottom. Wash sponge is immediately followed by rinse sponge in right hand. As the operator reaches lower end of lamp with wash sponge he drops it, takes rag from pocket, grasping upper end of lamp with it, and places it in lampholder. Purpose of rag is to provide necessary friction to turn lamp in preheat lampholders rather than any drying action. D—By filling the bucket only ½ to ⅔ full, room is provided for a one-hand squeeze against side of bucket. Heavy buckets should be used for this operation or foot should be braced against side of bucket. E—Excess water may be stripped quickly from a brush by hitting it angularly against side of bucket instead of carefully moving each side of brush over edge of bucket. F, G—In all maintenance operations the equipment used must be chosen with the fixture to be cleaned in mind. Time-saving equipment on one luminaire may slow the operator on another. Demonstrated here are two louver cleaning techniques—one with a sponge, the other a brush. The motion with the brush is obvious. With the sponge, the man moves from side nearest buckets toward himself, cleaning inside edges of both louver blades, up over the V, down the other side and out. He then repeats the motion but starts it on the side nearest himself, thereby saving the time otherwise used to move his arm back to the side nearest the buckets.

lumen and room maintenance are of particular concern. At least with the equations developed in this study, the values for these two factors are interdependent. A recommended addition to instrumentation would be timers to record the total hours of system usage.

Acknowledgments

The authors are indebted to Messrs. Ketch, Barr and VandenBoom of the Nela Park Application Engineering Department for helpful guidance, and to Messrs. Phillips, Hart, Cox, Miller, Lott, Dobras, Mackay and Thurman, engineers in training, for long hours of assistance in compiling the data for this test.

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DISCUSSION

G. M. MARKS*: Any contribution to the question of maintenance is good. This contribution to the subject is extremely valuable. There has been much discussion as to what occurs in our design before a lighting system is installed, but far too little on what occurs after a lighting system is in operation. There is a need for more practical papers of this type and members of the Society might do well to take up the offer of the authors to assist in the setting up of tests such as these. We must be able to tell the user of lighting equipment precisely what will happen to his lighting system after it is in operation, in addition to being able to predict accurately what will happen when the system is first installed!

While the subject of realistic maintenance is being discussed, I would like to inject my own feelings. Probably in light of my experience with industrial and commercial users, it might be wise to talk of realistic non maintenance factors.

As we are aware, and as is pointed out by the authors, there are two major causes of depreciation: the lamp lumen depreciation and the dirt accumulation. My feeling is to attempt to eliminate one of these major causes from our talk on maintenance factors.

In this paper, I feel we have a valuable contribution to what I advocate. The paper points out that the mean lumen output of all lamps in an installation is the lumen output at 40 per cent of rated life (although this study applies to the 40 watt lamp, similar studies could produce similar data on other lamps). Why not publish this figure along with the initial figure, and then use it in our lighting calculations?

We then could determine a dirt depreciation factor following the methods outlined in this paper, and through other tests and methods previously used. A variety of tests on a variety of materials and under a variety of conditions could be used to determine these dirt depreciation factors. I understand the Lighting Maintenance Committee of I.E.S. is developing a Dirt-O-Meter to make tests to determine the light loss due to dirt.

This dirt depreciation factor could then be applied to our lighting calculations in combination with the mean lumen output of the lamp. In this manner we should be able to develop more realistic maintenance factors which should result in greater accuracy in our overall calculations and greater user satisfaction.

R. L. OETTING and J. W. TUTTLE*: There have been a number of proposals to separate the present "maintenance factor" into its component parts. The objectives have been to simplify illumination calculations, to increase their accuracy, and to dramatize the independence of the factors involved. Mr. Marks' current proposals suggest that the matter may be due for review again.

Such a review must not only investigate the desirability of new definitions and values but also the likelihood of universal adoption. Without full support, which would include adequate promotion and education, widespread confusion would result. Certainly, the type of depreciation data developed in this study is more readily applied to a separate dirt depreciation factor than to the traditional combination known as the "maintenance factor."

Mean lumen values have been published for some time for incandescent lamps and an increasing amount of data is available for fluorescent. Fluorescent lamps are long life sources and it takes a long time to obtain realistic, measurable data. It is necessary to complete life testing before lumen maintenance characteristics can be fully determined.

Another complication is the increasing use of simplified lamp replacement programs in which consumers are replacing lamps in large groups at 50-80 per cent of rated life. This, of course, requires that mean lumen values be published for the several terminal points as well as for full rated life. For this reason, some manufacturers have published lumen depreciation curves from which data can be selected.

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*Authors.

Special School Lighting Issue

The June issue of ILLUMINATING ENGINEERING will be especially devoted to School Lighting, a subject of vital interest to everyone in the lighting field these days. If your interests remotely include this vital lighting subject, you'll not only want to dig into this issue right away, but keep it handy for ready future reference.

Watch for this special issue of ILLUMINATING ENGINEERING in June.

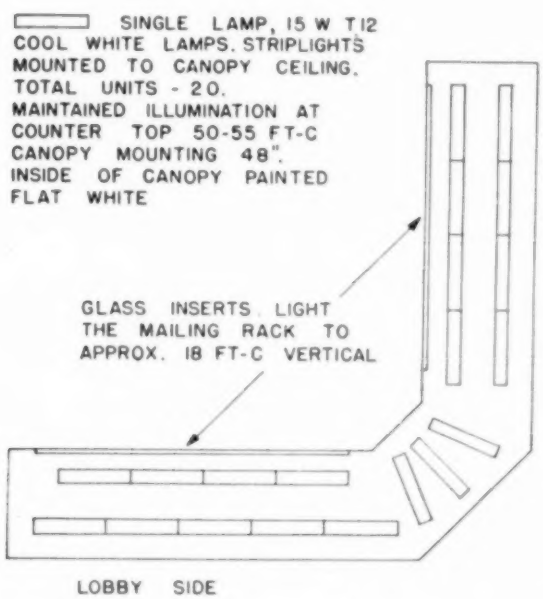
Overhead Canopy Modernizes Y.M.C.A.

MODERN LIGHTING for an old building is frequently the lighting engineer's most interesting challenge. The Syracuse Y.M.C.A., like many such buildings all over the country, is anything but brand new. Professional consultation on the lighting of its registration desk, however, has introduced a modern note of comfort and attractiveness. The installation described replaced a previous gloomy arrangement of two table lamps with 100-watt lamps, and bad brightness contrasts from a black desk.

The canopy over the desk, having the same dimensions as the base counter, now serves as one large lighting unit, providing high level (50 to 55 ft-c) with very comfortable brightness ratios. Twenty 15-watt fluorescent strips are installed in the arrangement shown in the drawing, mounted 8 inches above flashed opal glass panels. The glass is approximately 8 inches above the counter top. Fifteen-watt T-12 cool white lamps were suggested (a) for their lower surface brightness (as compared to 15-w T-8) and (b) one or two lamp failures would not seriously interfere with the lighting before replacement, as could be the case with 40-watt types.

The mail rack at the back of the area is also illuminated to approximately 18 vertical footcandles, by means of flashed opal glass inserts installed in the back vertical surfaces of the canopy. Interior surfaces of the canopy are painted high reflectance white. All glass panels are easily removed by tilting upward and sliding out, but otherwise cannot fall or loosen.

Glass surface brightness varies from 135 to 180 footlamberts. Counter top is of a coral color stainless composition; vertical surfaces of the canopy and counter are sand gray.


SINGLE LAMP, 15 W T12 COOL WHITE LAMPS. STRIPLIGHTS MOUNTED TO CANOPY CEILING. TOTAL UNITS - 20. MAINTAINED ILLUMINATION AT COUNTER TOP 50-55 FT-C CANOPY MOUNTING 48". INSIDE OF CANOPY PAINTED FLAT WHITE
GLASS INSERTS LIGHT THE MAILING RACK TO APPROX. 18 FT-C VERTICAL
LOBBY SIDE

Plans and recommendations for this installation were made by Carleton Peckham, Lighting Representative with the Niagara Mohawk Power Corp., Syracuse, N. Y. Data and photo supplied by Mr. Peckham.

An Improved Sphere Paint

By W. E. KNOWLES MIDDLETON
C. L. SANDERS

IN 1950 MIESCHER and Rometsch[1] reported a very high and uniform reflectance for plates of compressed barium sulphate, either alone or with gelatine as a binder, and suggested its use as a standard of whiteness. In this laboratory we attempted to reproduce their results, following their very clear and detailed instructions with the greatest care, but in several attempts we were unable to obtain nearly as good a white as they claim to have produced, even without the gelatine. Our best result, by an absolute method due to Taylor[2] and confirmed by direct comparison in a recording spectrophotometer, showed the compressed $BaSO_4$ to be somewhat yellower than magnesium oxide, its absolute reflectance being measured as 0.963 at $\lambda = 0.4\mu$, and 0.989 at 0.7μ. It is, of course, possible that our preparation was in some way at fault, but at least it can safely be stated that the use of barium sulphate as a standard white seems too difficult a procedure for ordinary use.

It was noted that the reflectance at the red end of the spectrum is higher than that of magnesium oxide,[3] and indeed higher than that of any other substance known to us. At the same time, it had come to our attention that a synthetic substance is readily available with physical properties rather like those of gelatine, but apparently entirely colorless, and we had tried this as a substitute for gelatine in making some of the compressed plates of $BaSO_4$. The substance in question is carboxymethyl-cellulose, often called C.M.C., and used in industry as a protective colloid. One cm of a one per cent solution in distilled water is almost completely clear throughout the visible spectrum, its transmittancy decreasing slowly through the ultraviolet and becoming small at about $\lambda = 0.22\mu$.

It occurred to us that a water paint with $BaSO_4$ as a pigment and C.M.C. as a binder might have interesting properties.

Four samples were made up, varying in their concentration of C.M.C. from 5×10^{-4} to 4×10^{-3} gm C.M.C. per gm of $BaSO_4$, the C.M.C. being the "medium viscosity" grade. The greater the concentration of C.M.C., the greater the durability of the paint, the greater the gloss, and the lower the reflectance. A concentration of 10^{-3} gms/gm was adopted as a satisfactory compromise between the various requirements. This produces a paint which adheres well to many surfaces and shows considerable resistance to abrasion, and at the same time is less glossy than magnesium oxide. Fig. 1 shows goniophotometric curves for the new paint and for MgO, with angles of incidence 0°, 45°, and 60°. The paint surface was prepared by spraying, and these curves might not apply to a brushed surface.

The absolute spectral reflectance of a surface covered by seven coats of the $BaSO_4$-C.M.C. paint was measured in the wavelength range $0.25 < \lambda < 2.2\mu$ by the method of Preston[4] as modified in this laboratory.[3] The results are shown in Fig. 2, together with similar data for a magnesium oxide surface one day old and (in the visible spectrum) for a surface covered by five coats of a commercial sphere paint used by many photometric laboratories on this continent.

The absorption bands at 1.4 and 1.9μ are almost certainly due to water bound by the C.M.C. To determine whether changes in relative humidity affect the results, the measurements were repeated (1) after keeping the surface for 68 hours in air dried over P_2O_5, and then (2) after exposure to a nearly saturated atmosphere for 24 hours. The three curves were identical to within the precision of the measurements, and we may consider the paint unaffected by changes in humidity. For two

Figure 1. Goniophotometric curves for $BaSO_4$-C.M.C. paint (full lines) and MgO (broken lines). The arrows show the angles of incidence.

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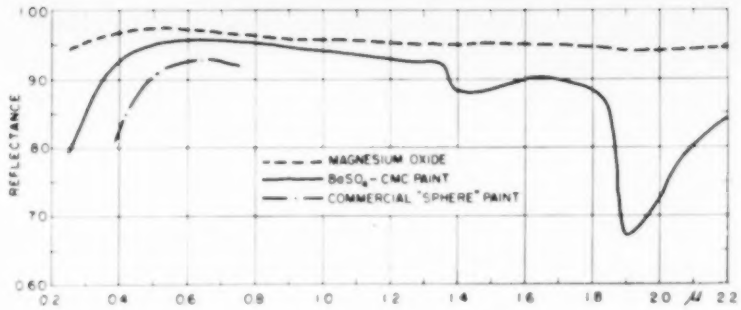

Figure 2. Absolute reflectance of MgO, $BaSO_4$ - C.M.C. paint, and a commercial sphere paint. The $BaSO_4$ - C.M.C. paint had 10^{-3} gm C.M.C. to each gm $BaSO_4$.

or three days after the last coat is applied, however, the reflectance rises slowly even in the visible, presumably because of the loss of free water.

Daylight has little effect on the color of this paint. Exposure for 33 days in a west window in summer raised the reflectance slightly, especially in the blue, while storage in the dark for a similar period raised it a very little in the red. The integrated reflectance Y and chromaticity co-ordinates x and y deduced from these measurements are shown in Table I.

TABLE I.—Effect of Light and of Darkness on $BaSO_4$-C.M.C. Paint.

Co-ordinates based on illumination by C.I.E. Source "A"

Condition	Y	x	y
One day old	0.975	0.4476	0.4077
After 33 days in west window	0.977	0.4472	0.4075
After 33 days in darkness	0.977	0.4477	0.4079

The effect of high temperatures has not been determined; but Preston's method as we use it concentrates a large amount of energy on a small area of the sphere wall, and no progressive change due to this has been discovered.

All the measurements so far reported were made on paint prepared from specially purified $BaSO_4$. The ordinary USP barium sulphate, which is extensively used by radiologists, costs about one tenth as much as the reagent grade. Similar measurements were therefore made on a surface covered with seven coats of paint prepared from this cheaper material. The results were very similar, the absolute reflectance of one sample made from USP barium sulphate even being about one per cent higher than that of the original sample referred to in Fig. 2. We may conclude that the USP grade is perfectly satisfactory for the purpose, and that a relatively inexpensive paint for large integrating spheres may be prepared in this way. The reason for the higher reflectance of the paint made from the USP barium sulphate is not known.

The suitability of this paint for integrating spheres was further tested by painting a sphere one meter in diameter and operating a 500-watt lamp at its center for several hours each day (turning it off each night). The ratio of the luminance of the sphere wall at a point shaded from the lamp to the extra luminance at an unshaded point is approximately proportional to $r/(1-r)$. This ratio was measured at intervals with a precision photoelectric photometer. After the first 12 hours operation there was no further significant change during the time the lamp was burning and none between evening and morning.

As may be deduced from Table I, the surface is very nearly white; indeed the difference in chromaticity between the values in the Table and C.I.E.

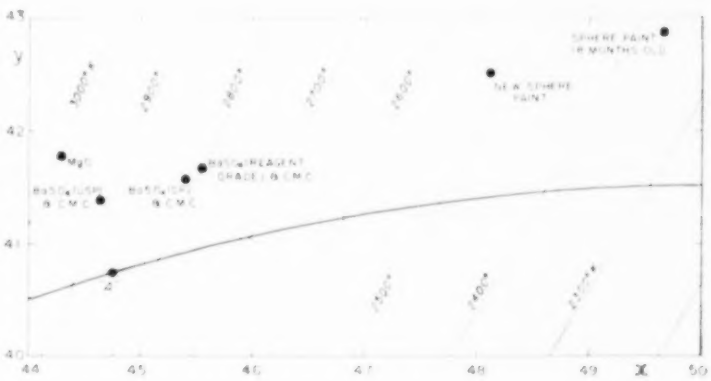

Figure 3. Portion of the C.I.E. chromaticity diagram, showing the Planckian locus with the chromaticity of C.I.E. Source "A" marked, lines of correlated color temperature, and the chromaticity of light from Source "A" emerging from spheres lined with various materials. The values are calculated.

Source "A" is less than a third of the standard deviation of color matching as given by MacAdam.[5] When such a paint is used in an integrating sphere, however, it causes the sphere to act as if it were a filter of spectral transmittance

$$t_\lambda = r_\lambda^2/(1 - r_\lambda) \qquad (1)$$

as far as light emerging from the sphere is concerned (r_λ = spectral reflectance).* For materials of high reflectance any variation in r_λ through the spectrum has a greatly magnified effect on the color of the emerging light, so that the measurement of this color affords a sensitive check on the precision of measurements of specular reflectance. It is, of course, necessary to use absolute values of reflectance in performing the calculation.

For several substances the correlated color-temperature[6] was measured visually and found to agree well with the chromaticity calculated by means of equation (1), making allowance for the fact that the light emerging from the sphere was always on the green side of the Planckian locus. Fig. 3 shows the calculated chromaticities, and also that of source "A." It would seem that the $BaSO_4$-C.M.C. paint, prepared from USP barium sulphate, is a somewhat better coating for the inside of an integrating sphere than even MgO, and much better than the sphere paint commercially available. We do not know why the USP product raises the color-temperature of the light, while the more expensive grades lower it. Electron-microscope photographs of the powders show that the USP may have a slightly lower range of particle sizes, but the difference is not marked.

It would seem that the addition of a very small amount of some purplish pigment might make the USP barium sulphate exactly neutral, but in view of the results of Miescher and Rometsch[1] on the result of adding extremely minute amounts of black, the procedure would probably be too tricky for practical use.

In preliminary experiments we tried magnesium oxide and carboxy-methyl-cellulose with very unsatisfactory results. It is suspected that the $Mg(OH)_2$ produced by hydrolysis reacts with the binder in some way.

*This is for light projected into the sphere. For light from a lamp within the sphere the formula becomes $t_\lambda = r_\lambda/(1 - r_\lambda)$.

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Staggered Side-Lighting In a Long Hallway

Rather than accent the length — 73 feet — of the hallway approach to the President's office of the Kroger Company, Cincinnati, by using a long row of lights down the center, it was decided to mount the luminaires at the joint of the wall and ceiling, staggered on 9-foot 3-inch centers. The 2-lamp 40-watt fluorescent units, with white glass diffusing lenses, provide an average illumination of 16 foot-candles in the 30-inch plane. Ceiling height is 10 feet; hall width is 6 feet. Walls are gray; carpet, gray green; ceiling, white acoustic tile. Installation by R. W. Brown, Cincinnati Gas & Electric Company.

Simplified Illumination Calculations For Large Area Perfectly Diffused Luminaires

By ROBERT D. BURNHAM

THE translucent medium in large area low brightness luminaires of the recessed or on-surface type is usually either plastic or glass, which in most cases approaches perfect diffusion. Of the two methods commonly used to predict the illumination performance, the lumen and interflection method, the former entails the usual coefficient of utilization tables and associated equations.

The Interflection method or its variations can be used by weighting the luminous area to the ceiling area to determine a fictitious average ceiling brightness and calculation carried out as a ceiling source. This can be done with a moderate amount of calculation. A third simplified method is described here for an approximation which has been found commercially accurate. If more accurate predictions are demanded, one of the foregoing methods may be used.

Figure 1 shows a typical arrangement of luminous areas. Ordinarily calculations would have to be carried out for each luminaire type. In this case the brightness of each diffuser is the same, allowing all configurations to be handled in one equation.

The following method is developed under the assumption that since the luminaire is totally direct, the effect of varying ceiling, wall and floor reflectances is materially lessened as compared to a luminaire with a large indirect component. Second, the ceiling area is assumed to be the same as the floor area. A third initial assumption is that the brightness is the same for each luminous geometrical square or rectangle. Following this assumption, it is obvious that the illumination is dependent upon the per cent of ceiling area made luminous.

In Table I the luminous area factor represents the ratio of the luminous area required to the ceiling area. Linear interpolation is allowed.

TABLE I.—Luminous Area Factor.

Illumination	Large Room	Medium Room	Small Room
10	.039	.030	.027
30	.080	.090	.118
50	.124	.150	.196
70	.187	.210	.275

Definitions of large rooms, medium rooms, and small rooms are the usual trade interpretation. (Large room, width four times height; medium room, two times height; and small room, width equals height.)

AUTHOR: F. W. Wakefield Brass Co., Vermilion, Ohio.

The Ceiling Percentage Formula (Same Brightnesses)

$$\textit{Square Feet of Luminous Surface Needed} = \textit{Luminous Area Factor} \times \textit{Ceiling Area}$$

(Equation 1)

This table assumes a uniform diffuser brightness of approximately 500 footlamberts. For similar lighting equipment where the brightness of the luminous surface might vary from unit to unit, one more factor has been added. This has been called the Luminaire Factor, which is an adjusted luminous area to compensate for the difference in brightness between luminaires. This is the same basic equation.

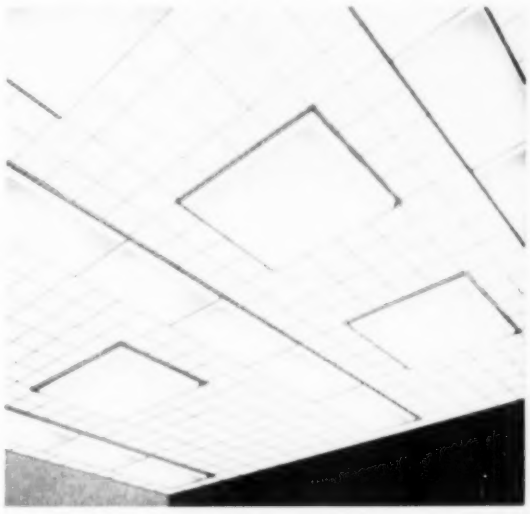

Figure 1. A typical arrangement of luminous areas.

The Ceiling Percentage Formula (Varying Brightnesses)

$$\text{Number of Luminaires Required} = \frac{\text{Luminous Area Factor} \times \text{Ceiling Area}}{\text{Luminaire Factor}}$$

(Equation 2)

TABLE II.—Luminous Area Factors.

Illumination	Large Room	Medium Room	Small Room
19	.026	.029	.038
39	.078	.087	.114
59	.129	.145	.189
79	.181	.203	.265

Typical luminaire factors developed for this formula are shown in Table III.

TABLE III.—Luminaire Factors.

Luminaire with Diffuser	Luminaire Factor
4' x 4' 6 lamps	16.3
4' x 4' 8 lamps	21.7
2' x 4' 4 lamps	10.9
1' x 4' 2 lamps	5.4
2' x 2' 3 lamps	3.2
2' x 2' 4 lamps	4.2

The luminous area factor tables were computed from equation 5. This equation is derived from the two basic equations below: The ratio of A_L to A is tabulated as the luminous Area factor.

$$E = \frac{F_L \times UF \times N}{A} \qquad \textit{(Equation 3)}$$

$$F_L = B' \times A_L \qquad \textit{(Equation 4)}$$

Substituting Equation 4 in Equation 3.

$$E = \frac{B' A_L \times UF \times N}{A}$$

$$\frac{A_L}{A} = \frac{E}{B' \times UF}$$

B' is a constant

$\frac{A_L}{A}$ is the luminous area factor.

(Equation 5)

Where F_L = Lamp lumens
E = Illumination in footcandles
UF = Utilization factor
A = Room area
B' = Diffuser brightness in footcandles
N = Efficieney of luminaire
A_L = Area of luminous surface of luminaire.

The simplification of these tables is based on the assumption that the effect of varying room reflectances is negligible. With most types of intensity distributions this is not practical; however, in this particular case the maximum practical deviation from the lumen method is in the order of 10 per cent.

These tables have been used to calculate the illumination level in existing installations and it appears to be as accurate as theory predicts. This method allows the geometrical areas to be selected and arranged to suit the designer with a minimum of calculation.

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New American Standard For Street and Highway Lighting

The Society's long awaited American Standard Practice for Street and Highway Lighting, first published in the August 1952 issue of ILLUMINATING ENGINEERING, has been approved by the American Standards Association and has received final polishing and is now available in booklet form. In every way the latest information available on this serious and frequently tragic lighting problem, this Practice is the result of studies by the I.E.S. Committee on Street and Highway Lighting since 1927, the last such Practice being published in 1947.

The new Standard Practice is 32 pages long, and is liberally illustrated with tables, charts and drawings. The booklet is divided into sections, such as: Classification of Streets and Highways; Classification of Luminaire Light Distributions; Design of Street and Highway Lighting; Situations Requiring Special Consideration. Tables and drawings illustrate and furnish information for ready reference on each of these sections. Appendices give background lighting information: Fundamental Aspects of Roadway Lighting; Data on Luminaire Performance and Computation; Typical Street Lighting Layouts; and Measurements.

The new American Standard Practice for Street and Highway Lighting represents a great step forward in improved street lighting for America's side streets as well as our superhighways. Lighting people concerned with this vital subject will find the new Practice a useful addition to their reference and field equipment. Copies may be ordered through the Publications Office, Illuminating Engineering Society, 1860 Broadway, New York 23.

Specifcation of Color-Rendering Properties Of Fluorescent Lamps

By CHARLES W. JEROME
DEANE B. JUDD

IN RECENT years, increasing attention has been paid to the color-rendering properties of light sources; that is, how objects of various colors appear under them. Prior to the advent of the fluorescent lamp, the measure of the color of a light source also, to a large extent, specified its color-rendering properties. Such lamps were incandescent and as such had spectral energy distributions (*SED*'s) similar to black-body radiators at relatively low color temperatures as modified by any filters which might be used in conjunction therewith. Therefore, the establishment of the color of a light source also established its spectral energy distribution, and thereby the appearance of colors under it.

This is not the case with fluorescent lighting. These lamps make possible relatively high levels of illumination of almost any desired color and the large selection of usable phosphors also makes possible considerably different spectral energy distributions for any given color. This latter variable may give rise to a considerable change in the subjective color of an object in going from an area lighted by one type of lamp to one lighted by another. The most common example of this change is found in going from a room lighted by incandescent lamps to one lighted by warm-white fluorescent. These lamps are a reasonably good color match but most deep reds will appear darker and grayer under the fluorescent lamp due to the deficiency of the latter in far-red emission. By the same token, some greens and blues may appear lighter and more saturated by this change due to higher density of radiant flux from the fluorescent lamp in these regions. It is this obvious change in colors, coupled with the advanced state of development of the sciences of photometry and colorimetry, which has been largely responsible for the increased interest in color-rendition measurements.

The present study was undertaken by the authors as members of a sub-committee on color of the American Standards Association's C-78 Committee investigating this subject. The results reported herein are by no means the complete story but merely represent a start in the amassing of the large amount of data which will be necessary for the final solution of this problem. It is hoped that these data will serve to indicate the intricacies of this problem, and serve as a springboard for future investigations.

As stated generically above, color-rendition of a light source is determined by the appearance of colors under it. This suggests that color rendition can be estimated by viewing objects of various colors under several light sources and judging which source gives the best color-rendition. This method is unsatisfactory for four reasons:

1. A random choice of test objects will usually not include those required for a critical test.
2. No criterion is set up for the correct color of the test objects.
3. The comparison leads to a qualitative answer only; that is, no strictly quantitative measure can be made.
4. It is subject to personal preferences as to the appearance of colors. These preferences are different for each individual, and may even be different for the same individual at different times.

Therefore, the first problem in this study is the establishment of a criterion for judging colors; in other words, setting up a standard light source under which the true colors of samples can be determined. Then the color-rendering properties of a test lamp can be judged on the basis of how nearly alike in color the same sample looks under it and under the standard.

Fluorescent lamps were first developed to have the same visual color as a black-body radiator at a particular temperature. This temperature became an integral part of the color nomenclature of these lamps, for example, 6500K, Daylight; 4500K White (Cool White); 3500K White; 3000K White (Warm White). Since these various "white" lamps differ widely in color, any object color will look different under one than under another. Consequently, a standard light source should be set up for each "white" fluorescent lamp.

In the rendition of colors, energy is emitted by the illuminating source and is reflected or absorbed in varying proportions by the test object depending

This paper is an extension of the data presented under the same title (and as Preprint No. 4) before the 1950 National Technical Conference of I.E.S. at Pasadena, Calif.

AUTHORS: Sylvania Electric Products Inc., Salem, Mass., and National Bureau of Standards, Washington, D. C., respectively.

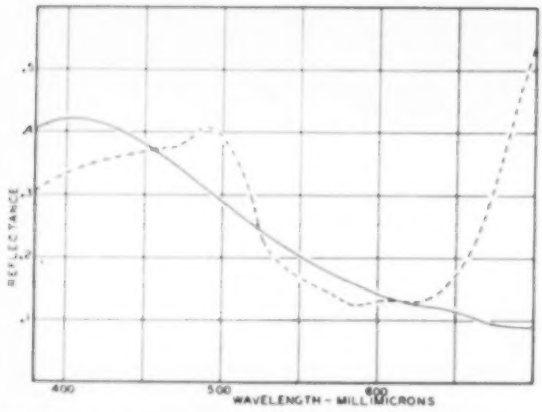


Figure 1a. Spectral reflectance of a metameric pair of blue colors.

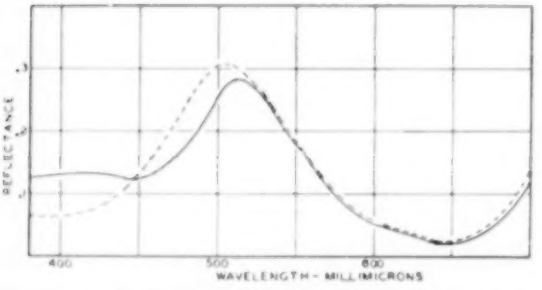


Figure 1b. Spectral reflectance of a metameric pair of green colors.

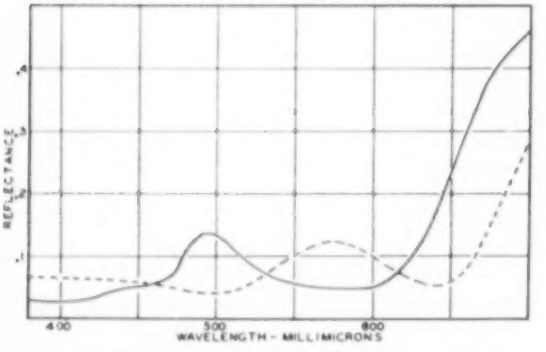


Figure 1c. Spectral reflectance of a metameric pair of olive colors.

on the wavelength of the energy and spectral selectivity of the object. Then, for the color of the object to be properly rendered, the source must emit energy within every one of a set of 5 to 10 wave bands in the visible spectrum in order that the selectivity of the test object in this band may properly alter the incident energy to give rise to the proper color sensation. Broad bands are specified here because if very narrow bands were used, certain discontinuous sources that have been found

TABLE I.—Spectral Reflectances of Three Pairs of Specimens Used To Test the Color-Rendering Of One Light Source Relative to Another.

Wavelength (mu)	Blue Specimens		Green Specimens		Olive Specimens	
400	0.419	0.333	0.130	0.066	0.029	0.066
410	.420	.343	.131	.068	.030	.066
420	.414	.351	.130	.073	.032	.065
430	.406	.358	.128	.086	.039	.063
440	.393	.363	.124	.106	.046	.061
450	.380	.368	.125	.132	.051	.058
460	.362	.371	.132	.163	.054	.055
470	.346	.376	.151	.200	.065	.050
480	.328	.386	.180	.242	.101	.046
490	.309	.408	.215	.281	.132	.042
500	.289	.391	.256	.303	.131	.040
510	.270	.348	.279	.301	.117	.043
520	.251	.277	.274	.282	.093	.052
530	.233	.221	.247	.252	.075	.068
540	.217	.183	.211	.213	.065	.085
550	.201	.167	.177	.182	.058	.101
560	.188	.153	.145	.148	.054	.114
570	.174	.141	.110	.116	.053	.123
580	.163	.129	.083	.087	.051	.124
590	.153	.126	.064	.068	.050	.115
600	.142	.132	.052	.056	.050	.100
610	.134	.132	.044	.048	.057	.083
620	.128	.130	.036	.039	.079	.070
630	.122	.131	.029	.032	.116	.058
640	.120	.144	.024	.026	.166	.053
650	.116	.173	.022	.024	.229	.055
660	.105	.217	.026	.030	.295	.078
670	.098	.279	.036	.043	.358	.118
680	.093	.367	.054	.064	.405	.166
690	.091	.462	.079	.096	.435	.220
700	.090	.546	.116	.140	.460	.280

to give good color rendition would be disqualified. The best example of this is probably daylight itself wherein the Fraunhofer lines make this a discontinuous source but do not interfere with the rendition of object colors. The CO_2 gaseous discharge tube is another example of a discontinuous source that gives very satisfactory color rendition.

A blackbody radiator fills the requirement of a suitable standard source; that of having energy in every broad wavelength band of the visible spectrum. Its spectral energy distribution is also well defined. Therefore, it seems logical to take a blackbody radiator at the same nominal color temperature as the lamps to be investigated as the standard for that color.

The establishment of a standard source overcomes the objection (2) of having no criterion for the correct color. If a standard observer is used to compute color specifications of the test objects for the standard and test sources, quantitative values may be obtained which provide a basis for overcoming objection (3). If, further, the object-color differences caused by passing from standard to test source are expressed in terms of number of just perceptible differences, objection (4) is overcome provided the test objects chosen are critical (objection 1).

Such a procedure has been used by the National Bureau of Standards[1] to test the degree of duplication of natural daylight by various artificial light sources. This procedure takes the form of compu-

tations of chromaticity coordinates, x, y, in the C.I.E. system[2] for three metameric pairs of colors that are so chosen that one pair (green) serves to detect deviations in the shortwave end of the spectrum between the source being investigated and the standard source; one pair (blue) similarly tests for the longwave and the third pair (olive) tests the middle of the spectrum. The spectral reflectances of these specimens are listed in Table I and are shown in Fig. 1. The chromaticity coordinates are then expressed in terms of a uniform-chromaticity-scale diagram, such as that of Breckenridge and Schaub,[3] so that equal distances anywhere in the diagram will represent approximately equally perceptible chromaticity differences, and the coordinate differences ($\Delta_1 x''$ and $\Delta_1 y''$) between the members of the pairs are determined. This is done for the standard and each source to be compared to it and the change in these differences (second differences, $\Delta_2 x''$ and $\Delta_2 y''$) in going from the standard to the test source is determined. That is, $\Delta_2 x'' = \Delta_1 x''_{(804.)} - \Delta_1 x''_{(\text{Fluorescent Lamp})}$ with a similar expression for $\Delta_2 y''$.

These data are reduced to a single deviation, D, for each test source from the standard by averaging the values of $\sqrt{\Delta_2 x''^2 + \Delta_2 y''^2}$ for the three metameric pairs. D in turn is converted to a "Duplication Index," I, by the transformation:

$$I = \frac{1 - 10D}{1 + 10D} \times 100.$$

This latter transformation is employed to arrive at an easily recognized scale of values. For example, by this transformation, an index of 100 represents exact duplication; an index of 50 is approximately the degree of duplication of gas-filled incandescent lamp light for natural daylight; and the index for monochromic light of wavelength 700 millimicrons for natural daylight is approximately zero.

This method of assessing the degree to which a test source duplicates the color rendition of the standard source is strictly valid for these three pairs of test objects only. It has general validity only to the degree that these test objects adequately represent objects to be viewed under the test sources. Furthermore, even with the number of test objects reduced to six, the computations are laborious and the method is quite unsuited for any quick routine check such as might be employed with a lamp factory. However, for all of the considerable number of sources of artificial daylight to which it has been applied, this method has yielded results in good agreement with the qualitative results of the subjective method; so it is proposed in this paper to use this method as a yardstick of the efficacy of shorter methods devised for the same purpose. Accordingly, by this method, the duplication indices, I, of four spectral distributions of cool white (4500K) for black-body radiation of 4500K, and four spectral energy distributions of warm white for blackbody radiation of 2854K (C.I.E. source A) have been computed with the following results.

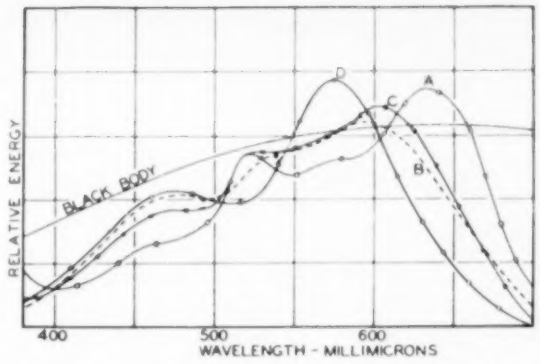


Figure 2. Spectral energy distributions — cool whites.

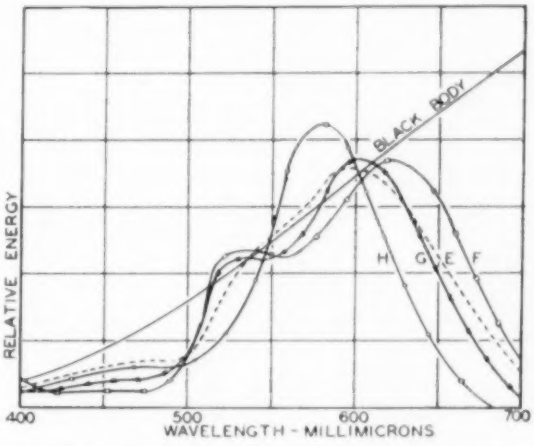


Figure 3. Spectral energy distributions — warm whites

Cool Whites		Warm Whites	
	I		I
A	69	E	62
B	75	F	69
C	76	G	54
D	58	H	45

The spectral energy distributions of these light sources without the mercury-lines are shown in Figs. 2 and 3 and are given with the mercury-lines in Table II.

In all the computations in this paper, the weighted-ordinate method of integration is used. The effect of the mercury lines energy of the fluorescent lamps is added to that of the phosphor emis-

TABLE II.—Spectral Energy Distributions.

	COOL WHITES					WARM WHITES				
λ	Std. (4500K)	A	B	C	D	(2854K)	E	F	G	H
400	54.8	4.0	7.6	5.8	8.7	7.9	3.9	4.0	2.0	3.1
*405.0	——	14.5	21.0	16.8	17.3	——	16.0	19.8	19.8	18.3
410	58.8	3.9	10.1	7.2	11.2	9.5	4.4	2.8	2.2	3.8
420	62.7	4.1	12.6	8.9	13.3	11.3	5.1	2.1	2.8	4.8
430	66.6	5.0	16.0	10.7	16.0	13.3	5.9	2.1	3.2	5.8
*435.8	——	37.5	51.5	40.0	44.3	——	38.5	48.3	46.5	43.5
440	70.4	6.0	18.8	12.5	18.8	15.5	6.6	2.0	3.6	6.5
450	73.9	7.0	21.9	14.7	21.4	17.8	7.5	1.9	4.0	7.3
460	77.2	7.7	24.0	16.1	23.3	20.4	7.9	1.9	4.4	7.7
470	80.4	7.9	24.7	16.4	24.2	23.1	8.0	2.1	4.4	7.9
480	83.3	8.4	25.0	17.0	24.3	26.0	8.2	2.2	4.6	7.9
490	86.1	9.2	24.7	17.2	24.0	29.1	8.6	3.6	5.8	8.2
500	88.6	10.4	24.4	18.2	22.7	32.3	9.5	6.8	8.2	8.6
510	91.0	13.5	26.0	21.5	22.3	35.6	13.5	12.4	14.4	10.5
520	93.3	16.2	29.0	25.2	22.7	39.1	20.0	20.0	21.4	13.7
530	95.2	15.6	31.8	25.5	24.7	42.7	25.0	21.0	22.4	17.0
540	97.0	14.9	33.2	24.8	29.2	46.4	28.5	20.8	22.4	24.2
*546.1	——	21.8	26.5	22.0	22.0	——	20.3	25.0	26.8	22.5
550	98.6	14.1	32.6	24.0	35.0	50.1	31.0	20.0	22.4	33.0
560	100.0	14.6	34.6	24.2	40.4	53.9	34.0	20.2	24.2	46.6
570	101.1	15.0	36.2	26.2	44.2	57.8	37.3	21.4	27.2	54.5
*578.0	——	4.1	6.2	5.0	5.2	——	4.8	4.8	5.2	4.4
580	102.2	15.5	37.8	28.3	44.1	61.7	40.6	23.4	31.2	57.9
590	103.0	15.9	38.8	30.5	40.8	65.6	43.4	26.4	35.8	54.5
600	103.6	16.9	38.8	32.4	36.0	69.6	44.0	29.2	38.0	48.5
610	104.1	18.8	37.1	31.8	29.0	73.5	42.4	31.8	37.2	39.0
620	104.6	20.7	35.0	30.2	23.4	77.3	40.3	33.0	35.0	30.4
630	104.8	22.2	32.0	27.5	18.5	81.3	36.5	32.8	31.0	23.4
640	104.9	24.6	26.8	23.0	14.6	85.1	32.4	30.6	26.0	16.8
650	104.9	20.9	22.2	18.5	10.6	89.0	27.2	27.2	20.6	10.8
660	104.8	18.2	18.9	14.8	8.0	92.6	23.5	23.4	15.6	6.8
670	104.4	14.0	14.5	10.5	5.2	96.3	18.8	18.2	10.4	3.0
680	104.1	10.3	10.9	7.5	3.0	100.0	14.8	14.0	7.4	0.8
690	103.6	6.3	7.0	3.4	1.2	103.3	10.2	10.0	4.4	——
700	103.1	3.8	4.0	1.3	——	106.9	6.5	6.6	0.6	——

*Mercury lines. Energy values are those in excess of energy per 10 mμ interval of the continuum.

sion after multiplying their measured energy by the factor: effective slit width of monochromator divided by the wavelength interval used in the weighted-ordinate integration as described elsewhere by one of us.[4]

As brought out in the above discussion, the spectral energy distribution of a light source is the determining factor in its color-rendering properties. This suggests the *SED* curve as a specification for this property. Two lamps having identical *SED* curves will have identical color-rendering properties and also identical color. Therefore, the establishment of a standard *SED* curve suffices to specify the color-rendering properties. However, there are practical limitations to such a specification. Lamps from different manufacturers may use similar blends of phosphors but may differ considerably in color. Also, there is a variation in color from lamp to lamp of a single manufacturer, the amount of the variation depending on the strictness of quality control measures employed. Consequently, concurrently with the establishment of a standard *SED* curve, tolerances on either side of it must also be established. These tolerances must be made loose enough so that maximum deviation from the standard at any one point will be allowed. When this is done for all points, the tolerances tend to lose significance since they would seem to allow maximum deviation at several, or all, points, whereas such an occurrence is obviously unsuitable. This objection could be overcome by making a single figure of merit similar to the "duplication index" described above, which would average the deviations from the standard, together with suitable tolerances thereon, as a supplementary part of the specification.

Another drawback in the use of *SED* curves as a complete measure of color-rendition is the difficulty in their interpretation, especially when lamps of considerably different *SED*'s are to be compared. This is indicated by the curves in Figs. 2 and 3. The comparison of any two such curves can lead only to qualitative estimates of the rendition of specific colors. For quantitative results recourse must be made to laborious computations similar to those used in the determination of the "duplication indices" above. What is most desired, then, is some simpler specification.

The *SED* curve implies that measurements of the energy in a number of narrow bands have been made. These bands are narrow and of sufficient number so that a continuous curve can be drawn. For example, the radiometer on which the *SED* curves of Figs. 2 and 3 were determined used bands 5 millimierons wide throughout. Therefore, one

simplification possible is to measure the energy in a smaller number of wider bands. This is the basis of a measure of color rendition of fluorescent lamps developed in Europe.[5, 6, 7] In their procedure, the per cent luminous energy (radiant energy weighted by the spectral luminous efficiency of the normal eye) in eight spectral bands, and tolerable limits to deviations therefrom are specified. The bands chosen as of equal importance in color rendition, and the tolerances set to accord with fluorescent-lamp control attainable in England in 1947 are:

Band No. 1	from 380 to 420 mu	±20%
Band No. 2	from 420 to 440 mu	±10%
Band No. 3	from 440 to 460 mu	±10%
Band No. 4	from 450 to 510 mu	±10%
Band No. 5	from 510 to 560 mu	± 5%
Band No. 6	from 560 to 610 mu	± 5%
Band No. 7	from 610 to 660 mu	±10%
Band No. 8	from 660 to 760 mu	±20%

These band limits are shown superimposed on a spectral energy distribution curve of a typical fluorescent lamp in Fig. 4.

Table III shows the distributions of luminous energy in per cent for the two standards (4500K and 2854K) and for the eight fluorescent lamps (see Table II and Figs. 2 and 3). The deviations from standard are also shown for the eight lamps.

A sample computation sheet for one of the lamps is shown as Table IV.

It is evident from the deviations from the standard given in Table III and the tolerances used by the British that a fluorescent lamp must be the standard used in the latter specification. This may be convenient for routine checks when such a standard has been established, but it seems to us desirable to try to establish a standard which will represent the best color-rendering light source available. This is one of the factors influencing our choice of blackbody radiation for this purpose. The greatest apparent drawback to the British procedure is the specification of eight different tolerances and the resultant difficulty in properly evaluating the overall effect of the deviations.

We have, therefore, tried averaging the deviations in order to arrive at a single numerical index which would be a measure of the color-rendering properties of the lamp in question and which could

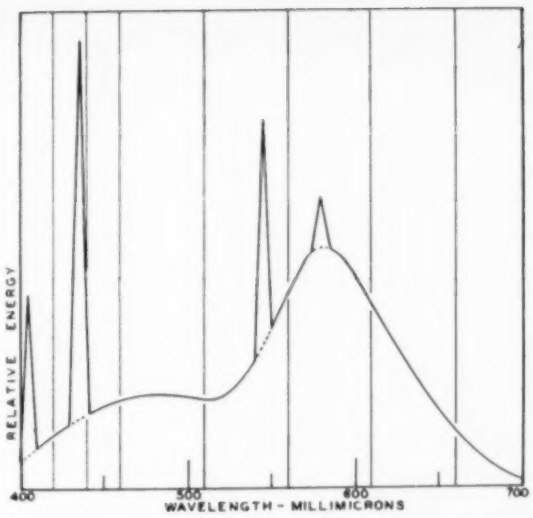


Figure 4. Spectral band limits in British specification.

TABLE III.—Luminous Energies and Deviations from Standard in Eight Spectral Bands.

COOL WHITES

Band	4500K L%	Lamp A L%	Lamp A ΔL	Lamp B L%	Lamp B ΔL	Lamp C L%	Lamp C ΔL	Lamp D L%	Lamp D ΔL
1	.02	.01	.01	.01	.01	.01	.01	.01	.01
2	.16	.42	.26	.35	.19	.33	.17	.33	.17
3	.56	.30	.26	.46	.10	.40	.16	.47	.09
4	8.63	5.68	2.95	6.75	1.88	6.41	2.22	6.61	2.02
5	39.17	44.92	5.75	42.27	3.10	42.21	3.04	40.26	1.09
6	38.50	34.81	3.69	39.76	1.26	39.23	.73	45.34	6.84
7	12.05	13.20	1.15	10.06	1.99	11.09	.96	6.84	5.21
8	.91	.66	.25	.34	.57	.32	.59	.13	.78
		ΔL:	1.79		1.14		.99		2.03

WARM WHITES

Band	2854K L%	Lamp E L%	Lamp E ΔL	Lamp F L%	Lamp F ΔL	Lamp G L%	Lamp G ΔL	Lamp H L%	Lamp H ΔL
1	.01	.01	—	.01	—	.01	—	.01	—
2	.06	.24	.18	.35	.29	.31	.25	.24	.18
3	.25	.17	.08	.06	.19	.11	.14	.15	.10
4	5.47	2.91	2.56	2.56	2.91	2.89	2.58	2.40	3.07
5	33.45	37.67	4.22	42.43	8.98	40.15	6.70	33.56	.11
6	42.59	45.89	3.30	39.19	3.40	43.47	.88	55.21	12.62
7	16.64	12.64	4.00	14.77	1.87	12.74	3.90	8.35	8.29
8	1.53	.47	1.06	.63	.90	.32	1.21	.08	1.45
		ΔL:	1.93		2.32		1.96		3.23

TABLE IV.—Computation of Radiant and Luminous Energy Distribution.

Lamp: B
Band System: British Specification

NOTE: The energies of the mercury lines are separately recorded at 405.0, 435.8, 546.1, and 578.0 millimicrons.

Wavelength	E	y	L = Ey
400 mμ	7.6	.0004	.0030
405.0	21.0	.0006	.0126
410	10.1	.0013	.0121
420	12.6	.0040	.0504
430	16.0	.0116	.1856
435.8	51.5	.0178	.9167
440	18.8	.0230	.4324
450	21.9	.038	.8322
460	24.0	.060	1.4400
470	24.7	.091	2.2477
480	25.0	.139	3.4650
490	24.7	.208	5.1376
500	24.4	.323	7.8812
510	26.0	.503	13.0780
520	29.0	.710	20.5900
530	31.8	.862	27.4116
540	33.2	.954	31.6728
546.1	26.5	.984	26.0760
550	33.6	.995	33.4320
560	34.6	.995	34.4270
570	36.2	.952	34.4624
578.0	6.2	.889	5.5118
580	37.8	.870	32.8860
590	38.8	.757	29.3716
600	38.8	.631	24.4828
610	37.1	.503	18.6613
620	35.0	.381	13.3350
630	32.0	.265	8.4800
640	26.8	.175	4.6900
650	22.2	.107	2.3754
660	18.9	.061	1.1529
670	14.5	.032	.4640
680	10.9	.017	.1853
690	7.0	.0082	.0574
700	4.0	.0041	.0164
Totals:	863.2		385.4462

Band No.	Wavelength Limits	E E%	L L%
1	380-420	45.0 5.2%	.0529 .01%
2	420-440	83.2 9.6%	1.3437 .35%
3	440-460	43.3 5.0%	1.7684 .46%
4	460-510	123.8 14.4%	26.0005 6.75%
5	510-560	184.4 21.4%	162.9349 42.27%
6	560-610	193.6 22.4%	153.2587 39.76%
7	610-660	144.0 16.7%	38.7875 10.06%
8	660-760	45.9 5.3%	1.2996 .34%
		863.2 100.0%	385.4462 100.00%

then be compared to its duplication index, I. For example, the magnitude of the deviations given in Table III have been averaged with the results as indicated. The correlation between these averages and the computed duplication indices is shown in Fig. 5. These data are shown in another way in Fig. 6 wherein the correlation between computed indices (I) and average differences between per cent luminous energy of blackbody and per cent luminous energy of the fluorescent lamp in each of the bands expressed as per cent of that of the standard is shown. This correlation is not as good as that shown in Fig. 5.

A further disadvantage of the British specification is the extremely low luminous energy in the

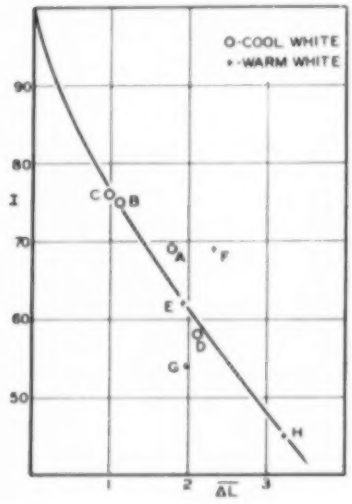
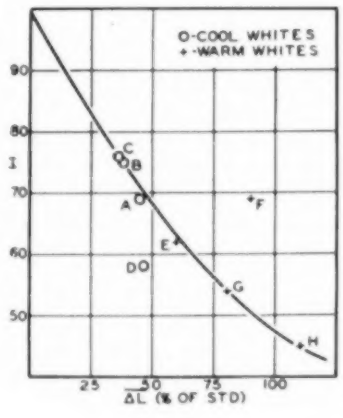


Figure 5. (left) Average luminous energy differences in British bands vs. duplication indices.

Figure 6. (right) Average luminous energy differences (per cent of standard) in British bands vs. duplication indices.



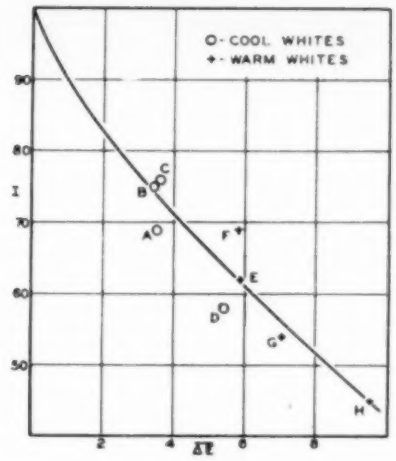
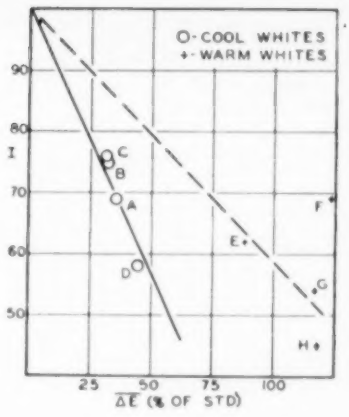


Figure 7. (left) Average radiant energy differences in British bands vs. duplication indices.

Figure 8. (right) Average radiant energy differences (per cent of standard) in British bands vs. duplication indices.



bands at the end of the spectrum due to the low sensitivity of the eye in these regions. Since the fundamental controlling factor in color rendition is the radiant energy emitted by the light source, a survey was made of this property of the test lamps in the spectral bands of the British specification. The results are given in Table V and shown in Figs. 7 and 8. In Fig. 7, the abscissa is the average difference between per cent radiant energy of the test lamp and per cent radiant energy of the standard. Fig. 8 shows the correlation between I and the average deviation from the standard per cent radiant energy in each band, the deviations being expressed as percentages of the per cent radiant energy of the standard in that band.

Fig. 8 indicates a possible correlation within each white although in each case there are deviations which are nearly as large as when a single correlation is assumed. Fig. 7 shows a much better correlation between duplication indices and average radiant energy differences.

Figs. 5, 6, 7, and 8 point up an observation which has been corroborated in the other studies reported herein. That is, the average of the actual differences in the magnitude of either luminous energy or radiant energy in a number of bands leads to a better correlation with the duplication indices than when these differences are expressed as a percentage of the standard values in each band and then averaged. Therefore, in the other results reported, it is the actual magnitude of the differences which are considered.

In view of the disadvantage of low luminous energies in the British bands at the ends of the spectrum another set of 10 bands was set up such that for a light source of equal spectral energy

TABLE V.—Radiant Energies and Deviations from Standard in Eight Spectral Bands.

COOL WHITES

Band	4500K E%	Lamp A E%	Lamp A ΔE	Lamp B E%	Lamp B ΔE	Lamp C E%	Lamp C ΔE	Lamp D E%	Lamp D ΔE
1	5.1	5.3	.2	5.2	.1	5.2	.1	5.8	.7
2	4.7	10.3	5.6	9.6	4.9	9.3	4.6	10.2	5.5
3	5.2	3.0	2.2	5.0	.2	4.4	.8	5.7	.5
4	15.0	10.1	4.9	14.4	.6	13.3	1.7	15.7	.7
5	16.9	21.0	4.1	21.4	4.5	21.9	5.0	22.0	5.1
6	18.1	18.3	.2	22.4	4.3	22.8	4.7	27.4	9.3
7	18.5	22.6	4.1	16.7	1.8	18.6	.1	11.4	7.1
8	16.5	9.4	7.1	5.3	11.2	4.5	12.0	1.8	14.7
			ΔE: 3.55		3.45		3.63		5.45

WARM WHITES

Band	2854K E%	Lamp E E%	Lamp E ΔE	Lamp F E%	Lamp F ΔE	Lamp G E%	Lamp G ΔE	Lamp H E%	Lamp H ΔE
1	1.4	3.7	2.3	4.8	3.4	4.3	2.9	4.2	2.8
2	1.6	6.9	5.3	9.2	7.6	8.9	7.3	8.4	6.8
3	2.2	2.0	.2	.7	1.5	1.4	.8	2.2	——
4	8.5	6.2	2.3	3.8	4.7	5.5	3.0	6.4	2.1
5	13.7	20.5	6.8	21.5	7.8	22.8	9.1	21.4	7.7
6	19.5	28.7	9.2	23.0	3.5	28.4	8.9	40.3	20.8
7	25.4	23.4	2.0	26.4	1.0	27.5	1.9	16.0	9.4
8	27.7	8.6	19.1	10.6	17.1	5.2	22.5	1.1	26.6
			ΔE: 5.90		5.81		7.05		9.53

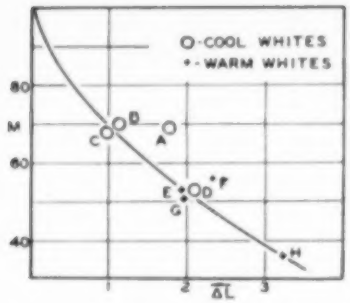
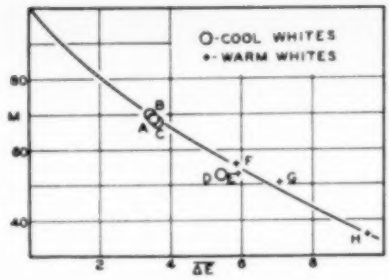


Figure 9. (left) Average luminous energy differences in British bands vs. modified indices.

Figure 10. (right) Average radiant energy differences in British bands vs. modified indices.



distribution approximately equal luminous energy would be obtained in each. The band limits are:

Band No. 1	Below 497.5 mμ
Band No. 2	from 497.5 to 517.5
Band No. 3	from 517.5 to 532.5
Band No. 4	from 532.5 to 547.5
Band No. 5	from 547.5 to 557.5
Band No. 6	from 557.5 to 567.5
Band No. 7	from 567.5 to 582.5
Band No. 8	from 582.5 to 597.5
Band No. 9	from 597.5 to 617.5
Band No. 10	Above 617.5

Since other than established band systems are being considered, still another set of bands has been investigated. These are of equal width, each 50 millimicrons wide (400-450, 450-500, 500-550, 550-600, 600-650, and 650-700 millimicrons). The average deviations from the standard in each of the sets of bands tested of the luminous and radiant energies of our test lamps are listed in Table V.

These data would seem to indicate no particular advantage of one band system over another. The British band system has been used for several years in Europe and although there have been rumors of dissatisfaction with the system, considerable data and experience with it have been obtained and special photometers built for simplified determination of the luminous energies in the separate bands. For these reasons there has been a great reluctance to change of the system and until a band system that can show decided advantages over the old system can be developed, there will be no point in making a change.

Up to this point, the discussion has been predicated on the duplication indices derived from the use of metameric pairs as explained earlier in this paper. This index has obvious advantages for the specific application for which it was developed, that is, as a measure of the efficacy of light sources to be used for color matching of filters, painted surfaces, and so on. In that application, the occurrence of metameric pairs of colors can be commonplace. In the more general application for overall illumination, the appearance of individual colors is more important than the comparison of pairs of colors. This has led some investigators[8] to study the color changes evinced by individual objects in going from one kind of illumination to another. It has also been suggested that commonplace objects should be used for this determination, such as butter, lettuce, coffee, and meat to mention a few. In view of these suggestions, a modified duplication index (M) has been developed and the correlation of our radiant and luminous energy data for the several band systems investigated above correlated thereto.

The modified index is derived similarly to the duplication index, I, using the same six test objects

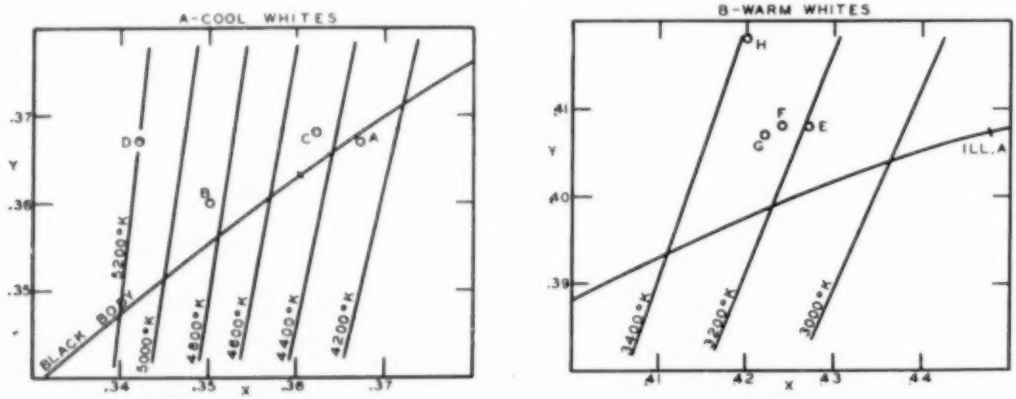


Figure 11. Chromaticities of lamps A to H on the C.I.E. color mixture diagram.

TABLE VI.—Average Luminous and Radiant Energy Differences in Three Sets of Band Systems.

SED	I	M	British Spec. L	British Spec. E	10 Bands L	10 Bands E	6 Bands of 50 mu L	6 Bands of 50 mu E
A	69	69	1.79	3.55	2.02	1.10	2.57	3.97
B	75	70	1.14	3.45	1.48	2.70	1.23	4.08
C	76	68	.99	3.63	1.54	2.48	1.26	4.68
D	58	53	2.03	5.45	2.49	4.42	2.77	6.77
E	62	53	1.93	5.90	1.82	5.16	2.21	7.15
F	69	56	2.32	5.81	2.12	3.32	3.18	7.27
G	54	51	1.96	7.05	2.89	5.34	2.42	8.80
H	45	36	3.23	9.53	3.59	7.50	4.86	11.33

comprising the metameric pairs. However, in the modification the changes in the color parameters in the rectangular uniform chromaticity scale are used instead of the second differences ($\Delta_2 x''$ and $\Delta_2 y''$). That is:

$$\Delta x'' = x''_{(\text{Std.})} - x''_{(\text{fluorescent lamps})}$$

and $$\Delta y'' = y''_{(\text{Std.})} - y''_{(\text{fluorescent lamps})}$$

Then, as with I, a single deviation, D, for each illuminant is obtained by averaging the six values of $\sqrt{\Delta x''^2 + \Delta y''^2}$. M is then derived from D by the transformation:

$$M = \frac{1 - 10D}{1 + 40D} \times 100.$$

The modified index, M, for our eight fluorescent lamps for their respective blackbody standards are computed to be:

Cool Whites		Warm Whites	
SED	*M*	*SED*	*M*
A	69	E	53
B	70	F	56
C	68	G	51
D	53	H	36

The correlation between these indices and the luminosity and energy analyses of the several band systems show that the correlation in the British band system is fully as good as that in the others. These relationships are shown in Figs. 10 and 11.

Before closing, it should be mentioned that the fluorescent lamps used in this study were chosen at random from several different production lots and from different manufacturers. Consequently, they are not all of the same color, nor do they match the color of the blackbody radiators chosen as the standards. The position of the lamps on the C.I.E. Color Mixture Diagram is shown in Fig. 11. The duplication indices of these lamps (both I and M) might be raised somewhat if the standard chosen in each case were the blackbody radiator of the nearest color temperature.

In summary, the conclusions arising from the present study are:

1. The spectral energy distribution of a light source is the only complete specification of its color-rendering properties.

2. A single index is required to supplement the *SED* curve to give an overall quantitative measure of the color rendition. When two *SED* curves coincide throughout, there is no need for the index since the color rendition of the two light sources will also be identical. The need for the single index arises to evaluate the relative merits of two lamps whose *SED* curves do not coincide.

3. Equipment for the precise determination of *SED* curves is too complicated and expensive for universal use. Therefore, a simpler procedure is required.

4. The measurement of relative energies in a finite number of spectral bands fulfills the requirements of number 3 above.

5. The use of the eight wavelength bands proposed by the British is recommended until such time as a selection of bands showing superior utility is developed.

6. The use of radiant energies in the spectral bands is recommended rather than the use of luminous energies. Radiant energy is the fundamental parameter in color rendition and the data contained herein show better correlation between duplication indices and energy relationships.

7. The single index suggested for color rendition of a lamp is the average difference between lamp and standard in per cent radiant energy within the eight British bands. Indices based on differences expressed as per cents of energies of the standard within the same wavelength band show poorer correlation with the duplication indices.

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Time Versus Luminous Ceilings

By DOMINA EBERLE SPENCER
LEONARD F. MARTIN

FOUR YEARS have passed since the first luminous ceilings were designed on the basis of the interflection theory. (By a luminous ceiling is meant, in this paper, a uniform, perfectly diffusing source of light that covers the entire ceiling. Louverall and other ceilings which permit the lamps to be viewed from any angle are specifically excluded.) In this time, experimental work has verified the accuracy of the interflection theory and results obtained in the field have demonstrated its practicability. Luminous ceilings have been used in a wide variety of applications and have provided luminous environments tailored to human needs.

Time has also shown the pitfalls of poor design. Coefficients of utilization can be over one hundred per cent or practically zero. The luminous environment may produce excellent visual conditions or glare. Luminous ceilings may be designed to have high maintenance factors; or made fine dust collectors. Finally, luminous ceilings can be designed to fit the tight budgets required by today's building programs, or require astronomical figures to cover the costs.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, Sept. 8-12, 1952, Chicago, Ill.
AUTHORS: Dr. Spencer, Associate Professor, University of Connecticut, Storrs, Conn.; Mr. Martin, Martin Electric Products, Inc., Somerville, Mass.

Luminous ceilings no longer belong in the luxury class only. This is borne out by the fact that lighting engineers and architects in ever increasing numbers are designing luminous ceilings into run-of-the-mill type of buildings. How can we design the finest luminous ceilings for the lowest cost? The purpose of the paper is to help illuminating engineers, lighting designers and architects answer this question, by pointing out past mistakes.

Coefficient of Utilization

What is the highest coefficient of utilization we can hope to obtain with luminous ceiling lighting?

This depends, in the first place on the diffusing medium hung beneath the lamps. The optimum optical characteristics of this material should be[1] transmittance, 50 per cent; reflectance, 50 per cent; with no losses. The most satisfactory plastic found so far has the characteristics shown in Fig. 1. This material is nearly neutral with a slight increase in transmittance at the longer wavelengths. At 600 millimicrons the transmittance is 47 per cent and the reflectance is 46 per cent, with a loss of 7 per cent. Using the methods of calculation developed by Moon and Spencer,[1] the equivalent ceiling reflectance with this plastic is 74 per cent and the "logance" or efficiency is 67 per cent for a *carefully designed luminous ceiling.*

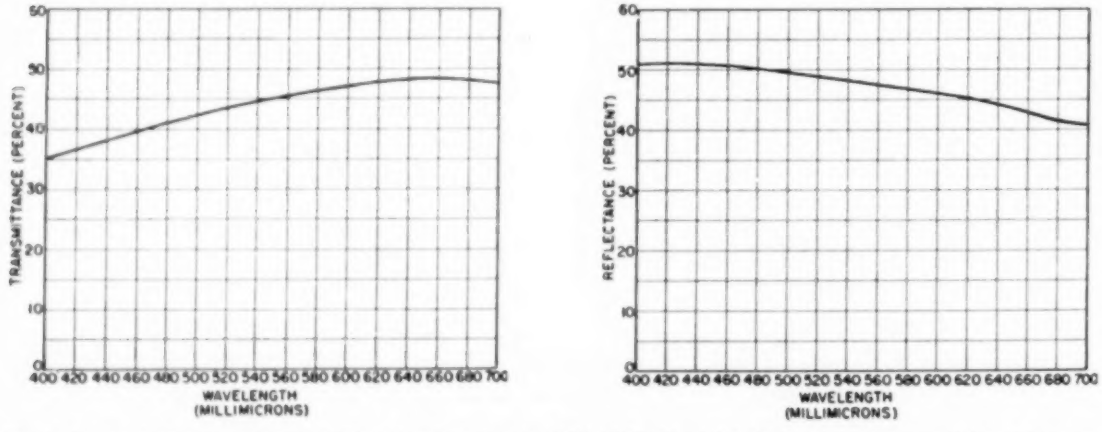

Figure 1. Spectral transmittance (left) and reflectance (with black backing) (right) for present composition of Marlux. To improve the uniformity of the luminous ceiling, a slightly more opaque sheet is now being employed than was used originally.[1] Measurements were made on the Hardy Spectrophotometer at M.I.T. On this same instrument, for the 1/8 in. Plexiglas used in the M.I.T. classroom,[11] $\tau = 0.480$ and $\rho = 0.352$ at $\lambda = 0.60\mu$.

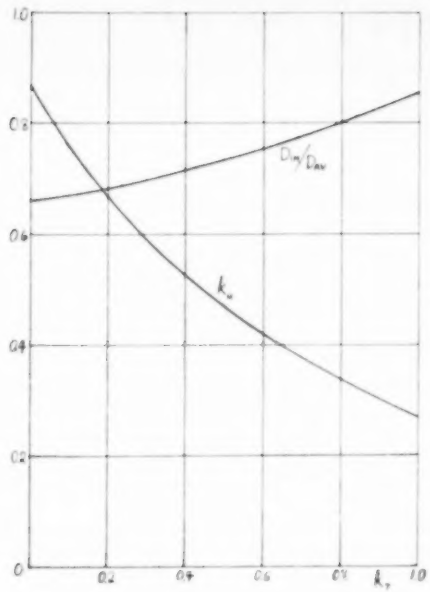

Figure 2. Coefficient of utilization k_w and (light on wall/light on desk) D_{1M}/D_{AV} versus domance of room k_r. Wall reflectance 0.500, ceiling reflectance 0.741, floor reflectance 0.300, logance of luminous ceiling 0.672. k_r = wall area/4 (floor area).

Fig. 2 gives the coefficient of utilization for various shapes of rooms in which recommended room reflectances are used. With careful design it is possible to obtain a coefficient of utilization of 0.86 in a very large room ($k_r \to 0$). In a typical schoolroom ($k_r = 0.50$) the coefficient of utilization is still 0.47 but in a cubical room ($k_r = 1$) the coefficient of utilization drops to 0.27. These values are higher than those suggested in the latest I.E.S. Handbook and higher than those estimated by good designers who, surprisingly, will fall into the error of thinking of complete luminous ceilings in terms of point sources.

How do we obtain such high coefficients of utilization? We follow six simple rules:

(1) Above the lamps use a *flat ceiling without obstructions.*
(2) Paint the *ceiling above the lamps white with reflectance* 80%.
(3) *Keep the luminous ceiling* comparatively *shallow* so that k_r of space above diffusing material approaches 0.
(4) *For uniformity,* keep distance between lamp centers less than 1.5 times the distance from lamp centers to diffusing plastic.
(5) *Average wall reflectance* must be at least 50 per cent.
(6) *Average floor reflectance* must be at least 30 per cent.

Occasionally a violation of these criteria may be necessary. The designer should realize that a penalty is attached to every violation.

In the machine shop at Brown University[2] the ceiling is covered with a maze of pipes, arranged in such a way that it is not practical to install a flat ceiling beneath them. Criterion (1) is violated. Pipes and ceiling were painted a good gloss white with a reflectance of 80 per cent, yet the equivalent reflectance of the enclosure was not 80 per cent but 67 per cent and the coefficient of utilization was consequently reduced by 30 per cent.

Other designers have used bare lamps in an unpainted enclosure (violation of criterion No. 2). Replace the flat white ceiling above the lamps by a black one and the coefficient of utilization of the luminous ceiling drops to a little more than one-third of its previous value. An excellent way of proving luminous ceilings inefficient! At first thought one might think that industrial reflectors behind the lamps would result in a more efficient design. This is an erroneous conclusion. It is far more efficient to paint the ceiling white and eliminate the reflectors. The good industrial reflector will emit 76 per cent of the light from the lamps. If the transmittance of the plastic is 47 per cent, the luminous ceiling will emit 36 per cent of the light from the lamps instead of 67 per cent. This would be a waste of both money and light.

In a group of offices at Brown University,[3] a 7-foot ceiling made it necessary to tuck the luminous ceiling between existing beams. Because the luminous ceiling was broken into several smaller sections, criterion (3) was violated. The "logance" was reduced to a little over 50 per cent of its normal value. Nearly half the light was lost because of an irregular type of luminous ceiling construction.

A simple unobstructed luminous cavity is shown in Fig. 3. Here the foregoing criteria are satisfied and theoretical predictions check field measurements.

Architects and engineers sometimes decide to raise the level of the plastic sheeting without reducing lamp spacing. A striped ceiling results, if the 1.5 to 1 spacing of criterion (4) is violated (Fig. 4).

Another misconception is that a transmittance much higher than 50 per cent must be used so we will not lose too much light. But if the transmittance is increased, the lamps become plainly visible as bright bars on the plastic. This procedure defeats the purpose of a luminous ceiling for it introduces bright, glaring lamp images. Strange as it may seem this highly transparent sheeting may actually give a lower coefficient of utilization than materials which are excellent diffusors. The best luminous ceiling material[1] available, optically speaking, is

Figure 3. Above an early luminous ceiling (Leominster Federal Savings and Loan Association, Leominster, Mass.). Note absence of obstructions, good lamp spacing and long runs of plastic of width 3 ft. This form of hanging system has been superseded by a simple yet rigid network discussed under "Maintenance."

ordinary tracing paper. The transmittance is 60 per cent and the reflectance is 38 per cent (less absorption than optical glass) yet the equivalent ceiling reflectance is 79 per cent, the "logance" of the luminous ceiling is 0.776, and the coefficient of utilization in large rooms with 30 per cent floor reflectance is 1.013. Tracing paper gives the highest coefficient of utilization of any material tested,[1] over 100 per cent — yet it hides the lamps, provided the 1.5 to 1 criterion is satisfied. Several transparent sheets with transmittances of over 70 per cent give lower coefficients of utilization. Thus, we conclude that it is *false economy* to increase the transmittance of the diffusing sheet much above 50 per cent.

Luminous ceilings may be installed in rooms in which the average wall and floor reflectances are below the recommended values of 50 per cent and 30 per cent. Even if highly reflecting wall paints and floor coverings are used, the average reflectances may be low because of large window and door openings or the effect of furniture. In a cubical office the coefficient of utilization with recommended reflectances is 0.27. But if the average wall and floor reflectances are only 10 per cent, the coefficient of utilization drops to 0.16. In important installations, the designer should always work out average wall and floor reflectances and use them in his calculations.

One more question may be asked on coefficients of utilization. Are the coefficients of utilization obtained from the interflection method accurate enough? The excellent experimental investigation of Churchill and Putnam[4] compared theoretical and experimental results on the distribution of

Figure 4. Reading room in the Boston Public Library. The lamps are placed too far apart. A striped ceiling results if the lamp spacing exceeds 1.5 times the distance from lamp centers to plastic.

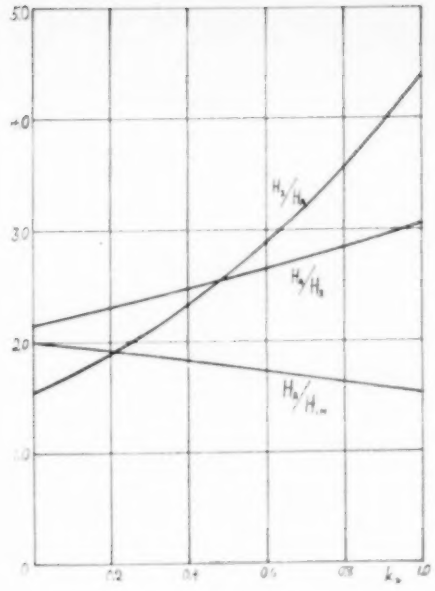

Figure 5. Adaptation brightness ratios for luminous ceiling lighted rooms with recommended reflectances. H_1, wall; H_2, ceiling; H_3, floor; H_4, work. The 3:1 ratio is satisfied for all shapes of rooms ordinarily encountered.

light in empty rooms lighted by luminous ceilings and found a maximum discrepancy of 4 per cent. A careful check of four offices at Brown University[3] showed an error of ± 10 per cent in rooms containing furniture. Similar results have been obtained in numerous other luminous ceiling designs.

Quality

Is the distribution of light in luminous ceiling lighted rooms satisfactory? The problem is best treated by considering the following:

(1) Distribution of light on horizontal surfaces.
(2) Quantity of light on vertical surfaces.
(3) The 3:1 adaptation ratio.
(4) Maximum quantity of light without glare.
(5) Specular reflection.
(6) Objectionable shadows.
(7) Modeling shadows.

If the walls are at least one-tenth as bright as the luminous ceiling,[5] the quantity of light incident on the desk tops varies by no more than 3:1 between the center of the room and the darkest corner. Ordinarily, the variation will be considerably less than 3:1.

Fig. 2 shows the ratio between the quantity of light incident on a vertical surface near the wall and the average quantity of light incident on a horizontal surface. In all cases, the quantity of light incident on the vertical surface is at least two-thirds of that incident on the horizontal surfaces, if recommended reflectances are used. For example, if we are designing a luminous ceiling for a control room where it is important to see writing on a horizontal desk and to read vertical meters on a wall panel we can have 100 lumen ft^{-2} incident on the desk and 80 lumen ft^{-2} incident on the meter (if $k_r = 0.80$).

The most important single criterion of quality is the 3:1 adaptation ratio[6] recommended by the first Committee on Standards of Quality and Quantity of the Illuminating Engineering Society. According to Fig. 5, this criterion is satisfied for wall, ceiling, and floor in nearly all shapes of rooms provided the average wall reflectance is at least 50 per cent and the average floor reflectance is at least 30 per cent. It is here assumed that the eyes are adapted to a printed page of reflectance 65 per cent lying on a desk. Since the state of adaptation of the eyes will not vary up or down by more than three, no matter how the eyes wander about the room, the eyes will always be nearly adapted to the work. Visual conditions are optimum and visual tasks are performed well and without fatigue. Such a luminous ceiling is shown in Fig. 6.

At a recent local I.E.S. tour, a luminous ceiling lighted office was inspected. The comments of the majority of those present were that the lighting was comfortable at 100 lumen ft^{-2}, but intolerable at 200 lumen ft^{-2}. Many illuminating engineers concluded that 200 lumen ft^{-2} from a luminous ceiling is always glaring. When asked if the ceiling might appear too bright because the walls were too dark, one illuminating engineer said that brighter walls would increase the flux to the eye and add to the glare! Of course, the difficulty was not the quantity of light. The only trouble was that the reflectances of walls, floor, and furniture were too low; contrasts were not 3:1 but 50:1. The fact is that all of us are accustomed to essentially the light distribution of a luminous ceiling outdoors on an overcast day at 1000 lumen ft^{-2}. And most people find these outdoor conditions among the most restful ever encountered. People say they have "too much light" when actually there is "too much glare." A properly designed luminous environment is not glaring, and so, no matter how much light we use — up to daylight levels — there is not too much light. With luminous ceilings, one can enjoy the ability to see fine detail that results from large quantities of light, without being aware that a large quantity of light is being used.

If polished surfaces such as a slide rule, a metal scale, or a draftsmans triangle are being used, the

luminaire will be reflected in the mirror-like areas. But if, as with a luminous ceiling, the luminaire is no more than three times as bright as the work, the 3:1 adaptation criterion will be satisfied. A luminous ceiling reflected in a steel scale makes the details stand out with high contrast. If a luminous ceiling is reflected in a glossy photograph, contrasts are slightly reduced. But this reduction of contrast is much less than would result under troffer systems or louvered fixtures.

Specular reflection also enters even when surfaces are not perfectly specular, such as the paper from which you read. The reflectance of both ink and paper depend on the angle. At the specular angle the reflectance of the "black" ink may under certain conditions rise to more than 80 per cent and the printing may become invisible. Tests[7] show that this type of reflected glare is eliminated if the luminaire is no more than three times as bright as the work. Thus, with luminous ceilings, reflected glare is minimized provided that high reflectances are used and the 3:1 criterion is satisfied. This is the most important advantage of luminous ceilings over louvered fixtures.

Head and hand shadows can be very annoying if they reduce the amount of light incident on the work[8] by more than 10 per cent. In hospital operating rooms, head shadows are a source of many complaints from surgeons. If directional light sources are used, for some positions, the doctor's head intercepts a large fraction of the narrow beam of light. If a surgeon is working under 1000 lumen ft^{-2} from a luminous ceiling, there will be at least 900 lumen ft^{-2} even in the worst head shadow.

Are there sufficient shadows to give proper three-dimensional effect? Are luminous ceilings becoming to the human face? To obtain a good three-dimensional effect with transparent shadows the modeling ratio should[9] be between 2 and 6. If the modeling ratio is below 2 the lighting becomes flat and solid objects begin to appear two-dimensional. If it is above 6, the contrast tends to become unpleasant with loss of detail in the shadows or in the highlights. The recommended modeling ratios are realized with luminous ceilings if the floor reflectance is between 30 per cent and 50 per cent.

These facts make luminous ceilings especially suitable for schools, art museums, photographic studios and television stations. The ideal luminous environment for child development, described by Harmon[9] is realized. In portrait photography, production of moving pictures, or television, a wide variety of effects can be obtained by merely varying the wall and floor coverings. For more dramatic effects one luminous wall or a single concentrated source can be added. Or if you just want soft, becoming lighting in your own living room, luminous ceilings are ideal.

Maintenance

Maintenance of luminous ceilings means a great deal more than periodic cleaning. The following topics must be seriously considered:

(1) Collection of dust.
(2) Lamp and ballast replacement.
(3) Satisfying the building superintendent.
(4) Preventive maintenance.
(5) Design for permanence.

Contrary to the belief sometimes expressed in ILLUMINATING ENGINEERING and in the *I.E.S. Handbook*, a *properly designed* luminous ceiling is very easy to maintain. With proper design dust collects mostly on the bottom of the plastic. If this dust film is never cleaned it will finally reach a

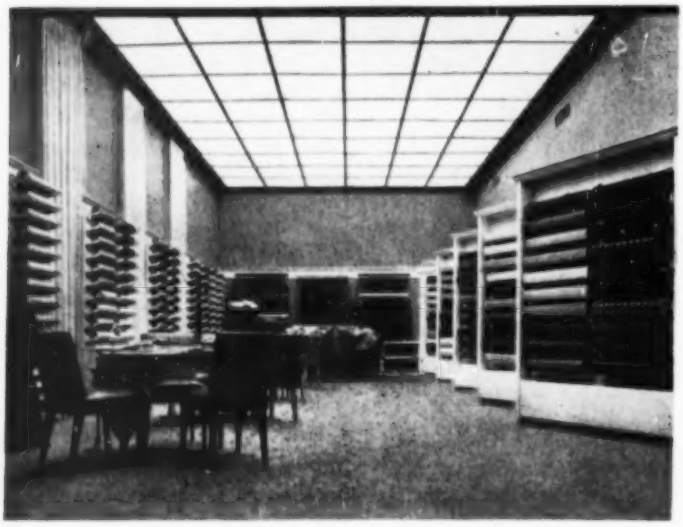

Figure 6. Sak's Fifth Avenue, Beverly Hills, Calif. A luminous ceiling installation for which the 3:1 criterion is satisfied.

Figure 7. Fitchburg Youth Library, Fitchburg, Mass. First commercial combination of acoustic fins and luminous ceilings.

transmittance of 97 per cent in a typical industrial environment.[10] Thus, dust decreases the quantity of light by only about 3 per cent if the luminous ceiling is carefully constructed. The decrease in quantity of light is almost solely associated with loss of light output from the lamps. Tests made at Brown University, in an unusually dirty location,[2] verified these predictions accurately over a period of 91 days. In this time, the light output had dropped to 96 per cent of its initial value. A recent check showed that the present quantity of light is more than 90 per cent of the original, even though it is nearly a year since the plastic has been washed and many of the lamps are two years old. Thus the predicted average maintenance factor of 87 per cent *appears* to be realistic. Similar results have been obtained in several luminous ceilings which have not been washed since they were installed three years ago.

The "breathing" which has sometimes been attributed to luminous ceilings apparently does not take place.[2] As there is a large volume of air in the luminous ceiling, the operating temperature of the air above the plastic differs very little from room temperature (about 1°F) and breathing is negligible.

To minimize service calls the fixtures should be of the simplest possible design. Emphasis must be placed on the quality of the fixtures and the component parts.

It is very important to explain the best maintenance procedures to the building superintendent. It has been found through experience that it is better to give explicit written instructions so that there will be no chance for misunderstanding in the event of personnel changes. To wash the plastic the roll can be placed vertically in a sink or bathtub and a shower or strong hose played down through the loose corrugations to remove the dirt. Temperature of water should not exceed 100°F. In the washing process, water soluble anti-static compounds, which are applied to the plastic at the time of manufacture, are removed. The plastic is a good dielectric and will attract dirt if it is not covered by a conductive anti-static film. Conventional hygroscopic agents which absorb moisture from the air to dissipate the charge have a short life and may leave a greasy residue on the plastic. Detergents should not be used. The anti-static compound must be able to dissipate the charge over at least a two-year period without leaving a visible film. After the plastic is washed it should be rinsed in a 2 per cent anti-static compound—98 per cent water solution, drained, and installed in position to dry without wiping.

Dust collects quickly in luminous ceilings if large openings are left. The Radio Shack in Boston collected dirt directly from Washington Street in large quantities through such apertures. There is a temptation to leave gaps around pipes which must pass through luminous ceilings. The plastic should be carefully cut to fit around such irregularities, if best maintenance is to be attained.

Cracks in the structural ceiling must be sealed so that dirt does not sift off the ceiling onto the plastic when the building vibrates. Failure to realize this in the Fitchburg Youth Library (Fig. 7) has allowed sawdust from the roof planking to sift down whenever workmen walk on the roof.

Engineering design of the suspension system is of great importance. The suspension system must be so designed that a mere glance at the ceiling shows that it is easy to install and remove the sheeting. The suspension system must also be light in weight,

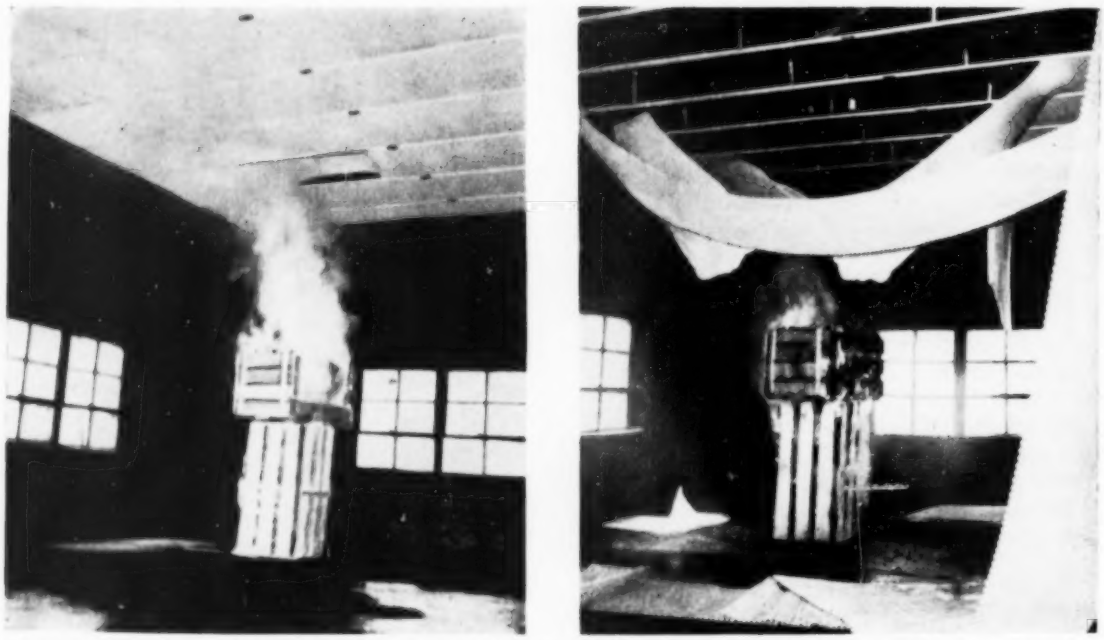

Figure 8. Test setup used 20′ x 20′ room of Martin's Marlux sheeting with four sprinklers mounted above. Wooden boxes with wood and excelsior contents, 322 lbs. of combustibles, were ignited near the floor at all four corners. Above left: This picture was taken 35 seconds after ignition. The upward draft from the fire is starting to lift the sheeting above. Above right: This was taken one minute 45 seconds after ignition. Two sprinklers have operated and brought down all but two strips of sheeting which are hanging by wires at the ends. Sheeting above the fire melted completely through. At this stage, temperatures were falling rapidly to safe levels.

easily and quickly installed. Yet it must create a network that will maintain supporting rails that were intended to be parallel in a parallel position and preserve original dimensions in spite of rough handling during maintenance and distortion of the building over the years.

The first commercial combination of acoustic fins and thin vinyl corrugated sheeting was made in the Fitchburg Youth Library (Fig. 7). It has been found that the thin corrugated sheeting provides, through its diaphramatic action, sufficient acoustical correction for average conditions. Where more acoustic correction is desired, fins made of acoustic absorbing material are preferable hung from the rails which support the plastic.

All materials used should be of the non-combustible or permanently self-extinguishing type. In buildings which require sprinkler systems, it has been found preferable to use materials which have been approved for use below sprinkler systems. Beside the test made by the Factory Mutual Laboratories (Fig. 8), it has been proven that sprinklers above the vinyl sheeting operate effectively in an actual fire at the Radio Shack.

The space above the plastic has also been found to make an ideal air-conditioning plenum. The ducts may run at the sides of the plenum with openings cut into them at intervals in such a way that air currents are directed toward the structural ceiling. It is preferable to have the returns in the floor of the room so that the filtered air moves down and around the convolutions of the corrugated plastic. It is possible to use the plenum as the return, but this introduces the hazard of dirt laden air being drawn into the plenum and allowed to settle on the plastic.

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8. See *Lighting Design*, p. 326.
9. Moon and Spencer: "Modeling with Light," *J. Franklin Inst.*, Vol. 251, p. 453-466; Harmon, D. B.: "Lighting and Child Development," ILLUMINATING ENGINEERING, Vol. XL, p. 199 (1945); Mortensen, William: "Pictorial Lighting," San Francisco, Camera Craft Pub. Co. (1947); "Flash," San Francisco Camera Craft Pub. Co., p. 134 (1947).
10. Spencer, D. E., and Malkiel, Selma: "A Photographic Investigation of Dust," *J. Franklin Inst.*, Vol. 245, p. 389-402 (1948).
11. Moon, Parry: "The New Approach to Room Lighting," ILLUMINATING ENGINEERING, Vol. XLIV, p. 221 (1949).

DISCUSSION

RUSSELL C. PUTNAM*: Interest in luminous ceilings is growing rapidly. Many new installations are being considered and illuminating engineers are having to evaluate the relative advantages and disadvantages of this new technique. This paper is particularly valuable, therefore, for that discussion which is concerned with fundamentals and applies to all makes of luminous ceilings.

This discussor is interested especially in the adaptability of the luminous ceiling construction for air diffusion as mentioned in the last paragraph of the paper. In work done at Case Institute of Technology a year ago and reported in ILLUMINATING ENGINEERING last May,[1] the luminous ceiling structure was shown to have excellent characteristics for air diffusion when the air passes from the plenum around the edges of the plastic. The results of lighting tests made in connection with the air diffusion studies indicate that there was no measurable decrease in illumination level as a result of the depreciation of the ceiling panels through the accumulation of dirt particles on the panels when air is passed through the plenum space for ventilation. This investigation is mentioned because it also is applicable to various makes of luminous ceilings and is not stated in the lists of references.

This paper is a welcome addition to the literature on luminous ceilings, particularly in respect to the information given regarding good and bad design practice.

Reference

1. Putnam, R. C.; Waite, R. W.; Seigel, L. G.; Bryan, W. L.: "Air Diffusion and Light Depreciation Tests of Luminous Ceilings," ILLUMINATING ENGINEERING, Vol. XLVII, No. 5, p. 274 (May 1952).

WILLARD ALLPHIN**: Considering that one of the advantages of a louvered ceiling is its ability to hide, from normal angles of view, a collection of ducts, pipes and wires, it severely limits the field of the plastic ceiling to say that its light cavity must be kept free of all obstructions.

Where available depth permits, it might be possible to keep the obstructions close to the ceiling and hide them with some inexpensive sheet material painted white, thus leaving an unobstructed light cavity. Have the authors investigated the economics of this?

R. D. BURNHAM†: I would like to commend the authors on their thorough coverage of this rapidly growing system of providing quality lighting. A number of advances have occurred in this field in the last few years and this paper gives a fine summary of the major developments.

Fig. 1 shows the spectral transmissions and reflectance of Marlux plastic often used as a diffuser for luminous ceilings. It might be clearer to many, to present the average transmission and reflectance since this is the factor used in calculations rather than the curve shown in Fig. 1. If this were done, it would be found that the average transmission was in the order of 43.6 per cent, reflectance 47.2 per cent and absorption 9.2 per cent. A comparison was made with $\frac{1}{4}$ inch Plexiglas as used in a classroom at M.I.T.; however, $\frac{1}{4}$ inch Plexiglas is seldom used as a diffuser for luminous ceilings. Usually a thinner sheet of corrugated Plexiglas is used, thus a higher transmission might be expected with the thickness of Plexiglas usually used. [ED.: This dimension, $\frac{1}{4}$ inch, in the caption of Fig. 1, was a typographical error in the preprint, and has been corrected to $\frac{1}{8}$ inch as printed here.]

A factor quite often forgotten in luminous ceiling design is the absorption of the diffuser. If the absorption of the diffuser is relatively high, the ceiling efficiency drops rapidly. The absorption should be low initially and should remain low throughout life. Some diffusers have the property of a low absorption initially in the order of 8 or 9 per cent which increases with time to perhaps 20 to 25 per cent in one to two years.

The authors point out that an increase in plenum depth drops the efficiency of the chamber rapidly. Tests being completed show that this decrease is logarithmic when K_r of the plenum is plotted against cavity efficiency. When this information is complete, the only major variable factor in plenum efficiency is the effect of obstructions within the plenum chamber. If Dr. Spencer and Mr. Martin are doing work along this line, a definite gap will be filled in the everyday application of luminous ceilings.

Accurate tests on large numbers of fluorescent lamps show, according to the lamp manufacturers' published data, that the lumen maintenance of the lamps themselves is between 82 and 85 per cent. If these values are correct, and there is every indication that they are, the maintenance factor for a luminous ceiling, or any other equipment using fluorescent lamps, could not be consistently higher than the lamp maintenance even if the lamp, the plastic, the cavity, and the room surfaces collected no dirt whatever. It is true that a portion of each manufacturer's lamps (approximately 50 per cent) do exceed by varying amounts the manufacturer's published ratings, but the other 50 per cent fall below the rated values. Maintenance factors recommended for general use should be based on average values rather than on values obtained from isolated groups of lamps.

Paint manufacturers also report that the reflectance of their light colored paints decrease. For example, a paint having initially a reflectance of 90 per cent can be expected to depreciate to approximately 85 per cent even if it is kept clean. The reduction in work plane illumination caused by the reduction of reflectance of the paint, both in the cavity and in the room, along with the reduction in illumination caused by dirt on all these surfaces, including the plastic, and decrease in lamp lumen output must all be comprehended by the maintenance factor. It would, therefore, appear illogical to assume that the maintenance factor could consistently be as high as 87 per cent.

The value of 87 per cent for a maintenance factor could not be directly compared to the values which would normally be found in the literature as the majority of authors would use a lamp maintenance value from 2 to 5 per cent lower than the one used by Spencer and Martin.

D. E. SPENCER and L. F. MARTIN*: We wish to thank Professor Putnam for his kind comments on our paper, and to apologize to him for the omission of a reference to his excellent paper on the combination of luminous ceilings and air conditioning. This paper was originally included in the list of references but was inadvertently omitted at an intermediate stage when the attempt was being made to fit our paper into the space allocated to it.

We have previously recommended that air conditioning ducts can be left in the lighting plenum and have laid out installations with the air conditioning system entirely con-

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**Sylvania Electric Products Inc., Salem, Mass.
†The F. W. Wakefield Brass Co., Vermilion, Ohio.

*Authors.

sealed above the diffusing plastic and without any anemostats. The experimental results of Professor Putnam have not only justified our recommendations, they have exceeded our most optimistic expectations.

In reply to Mr. Allphin's query, the point we want to bring out is this. The primary reason for installing luminous ceilings is to provide quality lighting; a secondary reason for deciding to use luminous ceilings is to hide a collection of ducts, pipes and wires. But if this is done the coefficient of utilization will be seriously reduced. The sacrifice is sometimes justified but the illuminating engineer should be aware that he is making it and should be able to estimate its magnitude. As Mr. Allphin has suggested, it is often possible to hide the ducts, pipes and wires, while retaining high coefficients of utilization, by covering them with the cheapest material that will provide a flat white surface. The cost of this additional sheet and the labor of installing it should be balanced against reductions of 30 to 50 per cent in the coefficients of utilization. If comparison is made at constant quantity of light, the use of the additional sheet will be found advisable if the resulting plenum is of sufficient height so that uniformity of the luminous ceiling is retained at a reasonable lamp spacing.

Mr. Burnham's comments are interesting and pertinent. I presume he realizes that neither the average transmittances and reflectances he suggests (average over what range of wavelengths, by the way?) nor the values at 0.6 micron mentioned in the paper are what we should be using. We should be using the transmittance τ evaluation for the particular spectral distribution $J(\lambda)$ emitted by the lamps that are being employed.

$$\tau = \frac{\int_0^\infty J(\lambda)\,\tau(\lambda)\,d\lambda}{\int_0^\infty J(\lambda)\,d\lambda}$$

We should have a value of transmittance and reflectance for each color of lamp available. At a time when "standard" lamp colors have been changing so frequently, however, we have rather used τ at a wavelength at which all lamps under consideration radiate quite a bit of light. As the $\tau(\lambda)$ and $\rho(\lambda)$ curves are reasonably flat, there will be little difference between the values obtained by any of the above processes.

With the $\frac{1}{8}$ inch Plexiglas used in the M.I.T. classroom there is adequate diffusion to produce a uniform luminous ceiling. The position of the lamps cannot be found without removing one of the panels. With the thinner sheets of Plexiglas used by Mr. Burnham the transmittance is undoubtedly higher but the lamps are plainly visible. This is precisely what we want to avoid in luminous ceiling design.

It is interesting to hear that Mr. Burnham is making tests on the logance of a luminous ceiling as affected by absorption and shape. Perhaps it would be helpful to bring to Mr. Burnham's attention the fact that such tests are quite unnecessary. All that is needed is a little calculation with Eq. (16) in a paper[2] published two years ago.

The predicted maintenance factor of 87 per cent was based on a somewhat smaller depreciation in lamp output than the 82 to 85 per cent used by Mr. Burnham. For the effect of lamp depreciation we used 88.4 per cent, taken from Table 7.01 of "Lighting Design"[3] (for a 40-watt fluorescent lamp, assuming lamps are replaced as they burn out). This appears to check for the lamps used in this test[4] which were slimline lamps purchased in 1949, operated on lead lag instant start ballasts. Perhaps, with other lamps and sequence start ballasts, the lower lamp maintenance factor of 82 per cent is justified. If Mr. Burnham's values were used, the maintenance factor for luminous ceilings would still be above 80 per cent. The effect of dust collection has been found to be only a few per cent. Both our research in rooms that are not air conditioned and Professor Putnam's investigations with forced air circulation indicate that the effect of dust collection on luminous ceilings is so small as to be difficult to measure. In a properly designed luminous ceiling, depreciation is almost entirely associated with the lamps.

For a detailed discussion of the effect of depreciation of room reflectances we would like to refer Mr. Burnham to Section 7.05 of "Lighting Design."[3] The reflectance of white paints varies from 0.80 to 0.90 (p. 126, reference 3). Consequently, it should ordinarily be possible to maintain the reflectance of 0.80 assumed in our calculations, especially within the lighting plenum where there will be very little collection of dust. Other room reflectances should, of course, be maintained values, if the maintained quantity of light is being calculated. The reduction in coefficient of utilization associated with paint depreciation is not directly proportional to the reduction in reflectance but is a rather complicated function. In this paper, instead of using an initial ceiling reflectance of 0.90 which would eventually drop to 0.85, as suggested by Mr. Burnham, we have used the conservative value of 0.80. Thus there is considerable justification for concluding that the data quoted in our paper are reasonable and sometimes conservative for a luminous ceiling designed to fit our specifications.

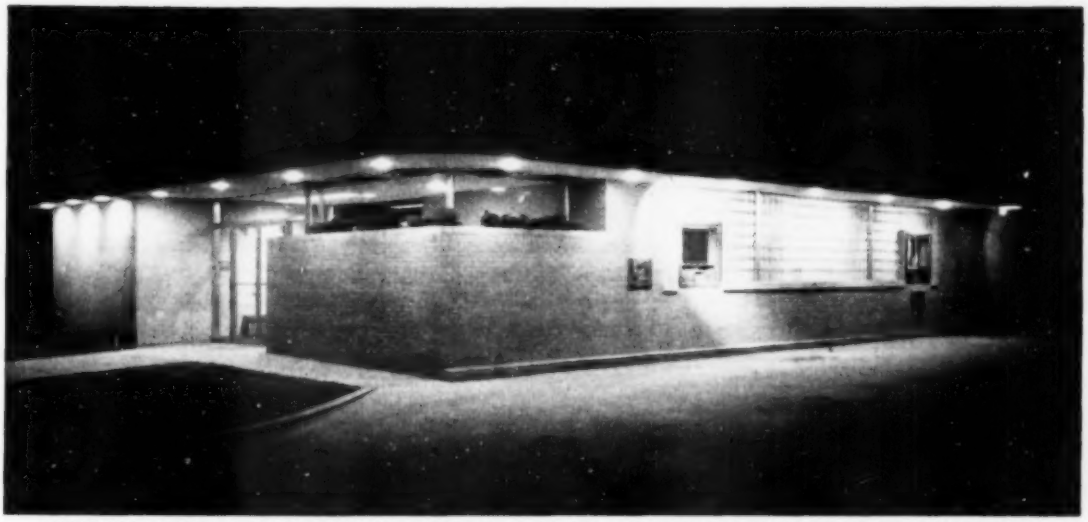
References

1. Putnam, R. C., Waite, R. W., Siegel, L. G., and Bryan, W. L.: "Air Diffusion and Light Depreciation Tests of Luminous Ceilings," ILLUMINATING ENGINEERING, Vol. XLVII, No. 5, p. 274 (May 1952).
2. Moon, Parry, and Spencer, D. E.: "Interflections in Coupled Enclosures," *J. Franklin Inst.*, 250, p. 151 (1950).
3. Moon, Parry, and Spencer, D. E.: *Lighting Design*, Addison-Wesley Press, Cambridge, Mass., 1948.
4. Spencer, D. E., Headley, R. B., and Martin, L. F.: "Luminous Ceiling Lighting for a Machine Shop," ILLUMINATING ENGINEERING, Vol. XLVI, No. 1, p. 26 (January 1951).

I.E.S. National Technical Conference

September 14-17, 1953 — **Hotel Commodore, New York City**

A.I.A. File No. 31



INSTALLATION AT MARKLAND AVENUE BRANCH, UNION BANK AND TRUST COMPANY KOKOMO, INDIANA.

Lighting a Drive-In Bank

LIGHTING OBJECTIVE: To provide night-time illumination for the teller's window and surrounding outdoor area of a drive-in bank.

GENERAL INFORMATION: The drawing shows a plan view of this area. The brick wall has a reflectance of about 45% and the pavement 25%.

INSTALLATION: General lighting is provided by Kirlin No. 1208 units (150-watt lamps) recessed in the canopy 9½ feet above the pavement. The window ledge receives additional illumination from a PAR-38 150-watt floodlamp. Illumination levels 150 hours after installation were as follows:

Ground, 2 feet away from wall, no automobile	10 ft c
Car next to drive-in window (left front fender)	28 ft c
Person in car making transaction (left arm resting on door, with glass down)	36 ft c
Window ledge	60 ft c

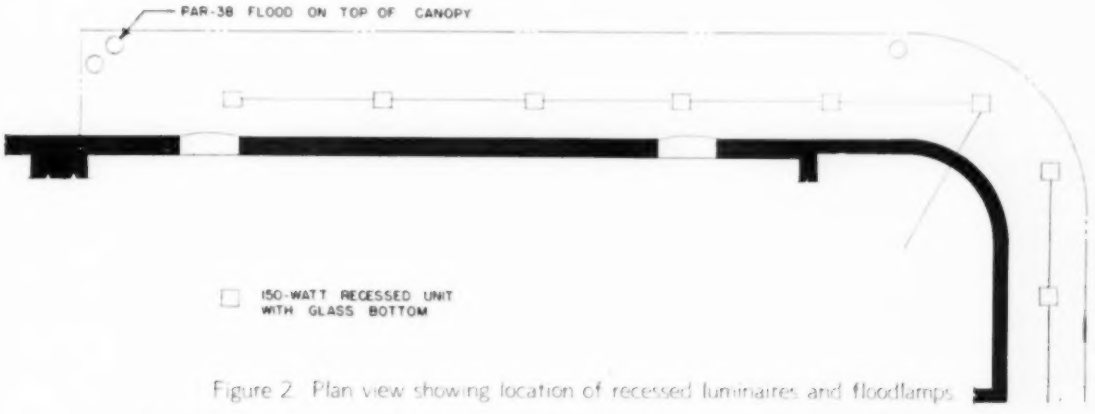


Figure 2. Plan view showing location of recessed luminaires and floodlamps.

Lighting data submitted by Dayton T. Fortner, Public Service Company of Indiana, Kokomo, Indiana as an illustration of good lighting practice and to aid in the design of similar installations.

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A.I.A. File No. 31

Questions and Answers on light sources

The I.E.S. Committee on Light Sources, under the chairmanship of G. S. Evans, has prepared this listing of answers to frequently asked questions.

Since the field has been fairly well covered in this series, this feature may be discontinued in the near future unless further questions are submitted by readers. Please send your questions to Society Headquarters.

What is meant by "general service incandescent filament lamps"?

These are lamps made for general lighting use on 115-, 120- and 125-volt circuits. (In Europe, general service voltages are 220 to 260 volts.) Below 150 watts, inside frosted bulbs are standard, while the larger sizes are made in both clear and frosted bulbs.

See page 8-18 and Table 8-3 of *I.E.S. Lighting Handbook*, Second Edition.

What is the most common cause of fluorescent lamp ballast failure?

The most common cause of failure of approved ballasts has been overheating, due to poor heat dissipation provided in the fixture, resulting in failure of the insulation of either the windings or the capacitor. Such failures frequently are part of a vicious cycle, in that the failure of the capacitor, or the short-circuiting of turns in the winding, usually leads to further overheating until a point is reached where a wire in or to the ballast is burned off, or a line fuse is blown.

In what way might failure of a fluorescent lamp ballast damage the lamps, wiring circuit, or fixture?

In the case of progressive failure of a ballast due to thermal causes, the failure or short-circuiting of either a capacitor or a portion of the ballast winding may permit abnormally high lamp currents to flow, which would definitely shorten lamp life if continued for an appreciable time.

Unless the wiring circuit is fused out of proportion to the wire size used, a ballast failure should not damage the wiring circuit. Even with properly fused circuits, the ballast may burn free before the fuse opens.

The thermal failure of a ballast likely will produce softened potting compound or a mixture of potting compound and capacitor impregnant that may run out and to the fixture parts. In certain isolated cases, the heat of the failing ballast may distill off vapors from the insulating materials, potting compound and capacitor impregnant. These vapors when combined with air may form an explosive mixture in the ballast compartment that may be detonated by the spark when the ballast burns free. Such a disruptive force may tear the fixture apart and cause it to drop its lamps and other removable parts. Fortunately, the proportion of violent failures of fixtures has been very small.

I would like to apply fuses to each fluorescent lamp fixture. What size fuse should I use, and how should they be connected?

Since supply line currents tend to rise under any of the conditions of approaching ballast failure, a measure of protection can be secured through the proper fusing of each fixture.

The proper size of fuse for such application will, of course, depend upon size of lamp used, the number of lamps per fixture, the voltage of the supply and the degree of power factor correction. Ordinarily the rated line current for each ballast is marked on the ballast label. Where the fixture contains more than one ballast, currents usually will be additive. The fuse that is rated to carry the smallest positive increment of current above that totalled from the ballasts in a given fixture probably would be the one to use.

This fuse should be connected into the ungrounded side of the line supply to the fixture. This would mean putting the fuse in the black wire to the ballast, or in the case of the choke-type ballast, between the ballast and the line connection.

Lighting for Foundries

Prepared by the Sub-Committee on Lighting for Foundries of the Lighting Study Projects in Industry Committee of the Illuminating Engineering Society

PREFACE

This report was prepared to guide foundrymen and illuminating engineers in solving seeing problems in foundries. It is the result of seven years of field studies of seeing tasks and of the effect of illumination upon the performance of these tasks in modern foundries. The study committee comprised illuminating engineers and representatives from the Malleable Founders' Society, Grey Iron Founders' Society, and Steel Founders' Society of America.

Many operating executives are using light as a tool in solving problems of industrial management. For example:

a. Productivity is increased through savings in working time since light of proper quality and quantity helps the worker to see more, better, quicker, and easier.

b. Labor Relations are improved through better morale and job satisfaction since work is made easier and surroundings are made more cheerful.

c. Safety Records are improved through quicker and easier seeing.

d. Control of Costs is gained through reducing spoilage and rejects since workers see more accurately.

e. Control of Quality is maintained through easier seeing for inspection, finishing, and maintaining close tolerances.

For those interested in having a sharp tool to help solve some of their industrial management problems, this report representing the combined thinking of foundry and illuminating engineers is well worth study.

COMMITTEE ON LIGHTING FOR FOUNDRIES

F. E. Mueller, *Chairman*

C. W. Briggs — C. E. Egeler

W. M. Caldwell — J. H. Lansing

J. W. Steiner

Approved by letter ballot of the Council of the Illuminating Engineering Society as reported at the Council Executive Committee meeting November 8, 1952.

1. Introduction

1.1—*Types of Ferrous Foundries*

1.1.1—*Production Characteristics*—**(a)** The typical *production foundry* is highly mechanized: molds are made by machines, transported by conveyors, poured continuously and the castings shaken out almost automatically. Such foundries usually specialize in long runs of castings from a limited number of patterns.

(b) The *jobbing foundry* specializes in the production of limited runs of castings from a large number of diversified patterns. The jobbing foundry may be partially mechanized, using molding machines, conveyors, etc., but not employing continuous pouring and other special features of the production shop.

1.1.2—*Product Characteristics*—**(a)** Ferrous castings are made in a vast number of sizes and shapes. Typical malleable castings range in weight from a few ounces to 5000 pounds, while gray iron and steel castings may weigh from a few ounces to as much as 100 tons. Castings may have almost any conceivable shape and degree of intricacy. Some castings can be used as they come from the foundry while others must be partially or fully machined. Some castings must be held to very close tolerances (several hundredths of an inch) while for others, dimensional exactitude is of little consequence.

(b) Since foundries vary quite widely as to their physical layout, production facilities and nature of their products, experience indicates that it is impractical to lay down inflexible lighting standards and layouts which will be appropriate for use in any and all shops. Therefore, these lighting specifications are very largely adapted to average or typical foundries making castings of average complexity, etc.; exceptional operations and requirements may necessitate special lighting treatments.

1.2—*Working Environment*

1.2.1—*Cleanliness of Atmosphere and Surroundings*—**(a)** In discussing the working conditions of any branch of industry, consideration should first be given to the materials employed in the process. The most important basic materials used in ferrous foundries are sand and molten metal.

(b) Sand for molding must contain sufficient moisture and clay to permit it to retain its "molded" form when the pattern is removed. It is therefore moist sand and not dust. This is also true of the sand used in the coremaking operations. When molds are dumped so that the castings may be removed, some dust arises. In the mechanized foundry this is removed at an air exhausted central shake-out location. In a jobbing foundry the dumping of the molds is done by a small number of men who employ wetting agents to settle the dust and exhaust hoods to draw off flocculent material. In later stages such as during cleaning and grinding operations, dry sand is present and air exhausting equipment is employed to reduce the dust concentration.

(c) Molten metal handling contributes fumes which are generally exhausted from the immediate area of the modern foundry. In pouring areas, for example, these fumes arise from the molds and unless adequately exhausted, may form deposits on lighting equipment.

(d) To summarize, as in any heavy industry, problems of cleanliness vary somewhat but maintenance of lighting equipment is always of primary importance.

1.2.2—*Types of Structures*—**(a)** In the early days of the industry, foundry buildings were generally laid out so that every molder would be facing a

window. In summer, added ventilation was gained through the open windows and light gained the year round. Today in mechanized foundries, however, most of the molders or machine operators work on conveyor lines where artificial light is required and found to be more uniform and dependable. Greater comfort is provided because workers are not exposed to the large expanses of bright sky.

(b) Buildings are generally of monitor or saw-tooth roof types. Usually the buildings are relatively high bay, especially those where large overhead cranes are employed for material handling or for the making and pouring of large molds.

1.2.3—*Utilization of Daylight* — The great majority of foundries operate normally on a one-shift basis, but in many mechanized plants, second and third shifts are also worked. Since maintenance of quality production involves the provision of good seeing conditions during *all* of the working hours, the lighting system should meet the seeing requirements of both night work and day work (especially on dark days in the northern states where a majority of the foundries are located). The recommendations of this report, therefore, provide desirable amounts of artificial light without dependence on daylight. For information on techniques for utilizing and controlling daylight, since most foundries already have large window areas for light and ventilation, the reader is referred to the I.E.S. Recommended Practice of Daylighting.

1.3—*Quality Control in Foundries*

(a) There are certain defects which occur in castings incident to methods of manufacture. These are no more prevalent or serious in the foundry industry than they are in any other industry. Nevertheless, if the foundry industry did not exercise control of the quality of the product, it is very possible that the quality would deteriorate greatly.

(b) Quality control in the foundry is, for a large part, a seeing task. A casting meets the tolerances specified because patterns are carefully checked against the drawings; flasks are inspected for fit; cores and molds are inspected for size, accuracy and alignment; core clearances are gauged prior to mold closing; castings are checked against templates and gauges; surfaces are inspected and defective castings are sorted out.

(c) All of the above operations can be made more positive and quicker by proper lighting. The workman, as well as the inspector, must be able to see his work clearly to prevent defective castings. For example, small pieces of sand must be removed from the pattern if the next mold to be rammed is to have a perfect mold cavity contour. The molder must see this small piece of sand in order to remove it.

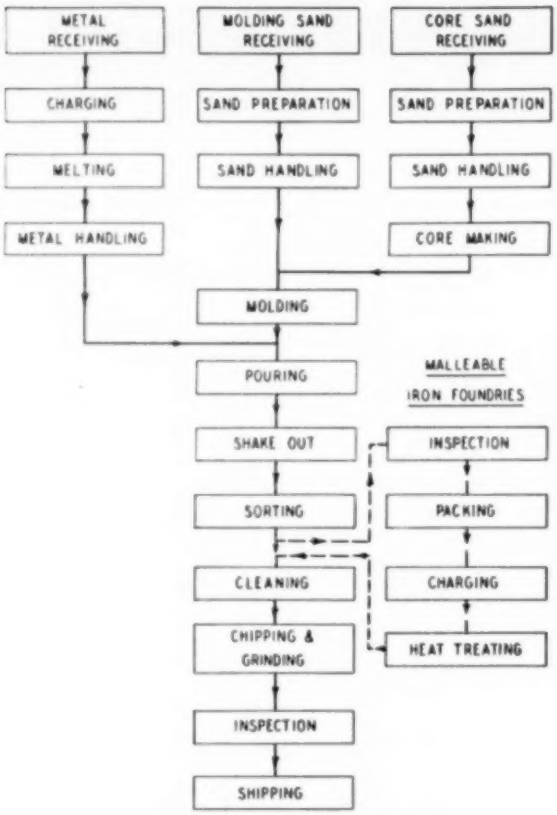


Figure 1. Foundry process flow chart.

2. Foundry Operations and Areas

(a) In general, the operational areas in a foundry may be grouped in four major classifications:

(1) Mold and core preparation (sand handling)
(2) Melting and pouring (molten metal preparation and handling)
(3) Finishing (grinding, cleaning and machining castings)
(4) Service and miscellaneous (receiving, shipping, inspection, etc.)

(b) The sequence of operations shown in Fig. 1 is typical of ferrous foundries. It will be noted, however, that in malleable iron foundries there is an additional operation inserted after the casting has been shaken out of the mold sand. This annealing operation is characteristic of malleable iron and is described under Section 4.

3. General Lighting Recommendations

3.1—*Footcandle Levels and Lighting Systems*

(a) For most of the foundry areas general illumination designed to meet the specific seeing tasks is recommended. The lighting requirements for the several processes are covered individually in the sections following. Both quality and quantity are specified, the quality determining largely the type of lamp and lighting unit and their location, and the quantity deter-

TABLE I.—Summary of Illumination Levels and Lighting Equipment for Foundry Areas.

Typical Areas	Footcandles Maintained in Service*	When Mounting Height Is	Use Lighting Unit Type
Annealing (furnace)	10	12 feet and under	A or B
Cleaning	20	12-20 feet	A, B or C**
Core making —		18-30	B, C or D
fine	50	30-100	D or E
medium	30	40-100	F
Grinding & Chipping	30 (plus supplementary)	**300-500 watt incandescent only.	
Inspection —			
fine	100		
medium fine	50		
medium	30		
Molding —			
medium	50		
large	30		
Pouring	10		
Shake-out	10		
Sorting	10		
Shipping & Receiving	30		
Storage	10		
Cupola charging	10		

*Current Recommended Practice — minimum values.

Typical Lighting Units (Open or Enclosed)	See Figure Number
Type A — Direct‡ filament units, 300 watts and under (wide spread distribution): porcelain enameled dome reflectors; silvered bowl diffusors; prismatic or mirrored glass reflectors; aluminum reflectors	2a
Type B — Direct‡ industrial fluorescent luminaires having reflecting surfaces suitable for foundry use, e.g., porcelain enamel, synthetic enamel†, plastic,† mirrored or prismatic glass, aluminum.	2b
Type C — Direct filament and mercury 300 to 1500 watt units (wide to medium distribution): aluminum reflector; prismatic or mirrored glass reflector; porcelain enameled metal reflector	2c
Type D — Filament or mercury reflector lamp assemblies	2d & e
Type E — Direct filament and mercury high bay 300 to 1500 watt units (medium spread to concentrating distribution): aluminum reflector; prismatic or mirrored glass reflector	2c
Type F — High bay units for 3 kilowatt mercury vapor lamps	2f

†Care should be taken to provide surfaces that non deteriorating which permit easy maintenance in atmospheres of heavy dirt content and corrosive fumes.
‡In certain areas such as core rooms, inspection areas, receiving and shipping rooms, where it is practical to maintain light colored ceilings and upper side walls, semi-direct luminaires providing an upward component of light will provide improved seeing and eye comfort.

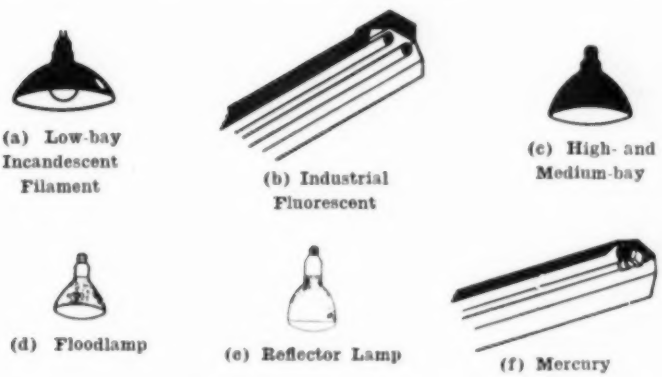


Figure 2. Typical luminaires suitable for use in Foundries (see Table I).

mining the footcandles *maintained in service*. The recommendations for the principal areas are summarized in Table I.

(b) Since the mounting height (in combination with the footcandle level) is a principal factor affecting the choice of the lighting units, Table I includes a compilation of typical lighting equipments and lamps suitable for the areas listed; this equipment is then grouped in terms of mounting height ranges. The suggested units are shown as a guide to the selection of luminaires particularly adapted to the specific lighting needs. They are on the basis of present day availability, and of course do not preclude the use of other or later equipment which provides equal or better light quality than do the luminaires listed.

(c) Lamp wattage and spacing, and other layout aspects, are not covered in this discussion. It is assumed that the services of a lighting specialist will be available, or published data on lighting calculations will be used to determine the number of units and their location, required to deliver the desired footcandle levels for each area.

3.2—*Brightness Environment — Painting*

(a) Well lighted areas contribute toward making the worker happier. The stimulation or psychological lift one gains from good lighting has an important bearing on the workers' morale. For instance, if allowed to choose their working conditions, workers would choose a cheerful atmosphere, such as provided outdoors by the sun. The foundryman also gets a boost to his morale from pleasant surroundings gained through the proper use of light and paint.

(b) The walls may be painted any suitable color as long as they reflect the desired percentage of light. Whenever practical, the reflectance (per cent of light reflected) of ceiling should be 75 to 85 per cent, upper walls 50 to 60 per cent, and dados 25 to 35 per cent.

(c) The finish of walls and ceilings and sometimes of machinery and equipment serves a multiple purpose in illumination:

(1) Sharp contrasts are reduced between work and surroundings, or luminaire and ceiling, when surfaces reflecting most of the light are used. This contributes to

greater worker comfort and less fatigue. Particular attention is directed to the desirability of providing an upward component of light to reduce brightness contrast between luminaire and background. These factors contribute to greater comfort and less fatigue.

(2) More of the light from the luminaire will reach the worker when it is reflected from surfaces having a high reflectance. This improves the overall efficiency of the lighting system.

(3) Colors may be selected for improved psychological environment. For example, bluish greens may be used to create an impression of coolness.

(d) No color-matching tasks restrict the selection of light sources or paints in a foundry. A conventional light source of almost any color quality may be used.

4. Specific Lighting Recommendations for Operating Areas

4.1—*Core Making Area*

The three general methods used to form sand cores are hand ramming, machine ramming and blowing. Hand and machine rammed cores are formed by packing the sand in the core boxes by hand or machine. Core blowing machines inject the sand into the core box and pack it tightly by means of compressed air. Core blowing machines are unique in that the core maker does not have to handle the sand.

4.1.1—*Seeing Tasks*— **(a)** The following operations are generally performed in making cores, regardless of the method of packing the sand.

(1) The two halves of the core box are cleaned by air blast and the cavities inspected for any foreign material or sand remaining from the previous core.

(2) The core box halves are joined (and sometimes clamped) together and placed on a core tray.

(3) The core box is filled and tightly packed with sand, reinforcing wires are inserted, when required, and the sand is leveled off at the top of the box.

(4) The core box is then carefully parted to leave the completed core or cores on the tray.

(5) The cores are briefly examined for flaws, and, when necessary, rough spots or heavy parting lines are smoothed over with a small trowel.

(6) The cores are set to one side, and the above operations are repeated for the next core.

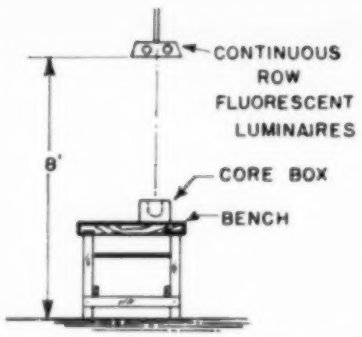


Figure 3. Lighting for core making.

(b) The most critical seeing tasks for the core maker are involved in steps (1) and (5). Thus the visual task is primarily one of inspecting intricate shapes involving horizontal and vertical surfaces and cavities. The severity of the task varies with the size of the cores, their intricacy and the degree of perfection required. Cores may range from the size of a small button to approximately 1 x 3 feet. A cluster of as few as six grains of sand could result in an imperfection. Since it is usually done on a piecework basis, core making is a rapid and continuous operation requiring an almost instantaneous inspection at frequent, but interrupted, intervals.

(c) The sand used is usually a medium brown, but black sand is also employed for some types of cores. Core boxes may be of metal or wood, the latter generally being finished with orange or black shellac. The contrast between the sand and metal boxes is fairly good, but it is extremely poor between brown sand and orange shellacked boxes or black sand and black boxes. Contrast and seeing conditions may be improved considerably by finishing the inner surfaces of wooden boxes with white paint. Metal boxes may cause annoying specular reflections if small high brightness light sources are employed. Bench tops having a light, natural wood finish are both practical and very desirable, for they can be kept clean easily and will provide a comfortable visual environment with low brightness ratios.

4.1.2—*Physical Characteristics*—Compared with other foundry areas core rooms are generally relatively small and clean, but they are sometimes located in the same general area with molding or other foundry operations. Truss heights may be fairly high, but are not necessarily so since generally little vertical clearance is required. Ceilings and overhead trusswork should be painted a high reflection factor white, and walls may be any light color with 50 to 60 per cent reflectance. The paint finish should be semi-gloss.

4.1.3—*Lighting Requirements* — **(a)** The amount of light required depends upon the size of the cores and the degree of perfection required. Maintained illumination levels of 30 footcandles should be provided for average core making, but lighting levels up to 50 footcandles may be found advantageous for core making requiring accurate control of contour and dimensions or where the core and box have particularly poor contrasts.

(b) Large area, low brightness light sources should be employed to minimize specular reflections from metal core boxes and to provide more uniform brightness on complex surfaces. Such sources, providing a wide distribution of light output, will also contribute to adequate illumination on vertical surfaces of core and core box cavities and will minimize shadows within the cavities. Since the luminaires may be mounted at heights of less than 12 feet, adequate shielding must be provided to prevent annoying glare.

4.1.4—*Lighting Recommendations* — **(a)** Industrial luminaires providing at least 13-degree shielding for fluorescent and 17 degrees for filament lamps are well suited to the requirements of core room lighting. For low mounting heights (under 10 feet) two lamp fluorescent luminaires equipped with a longitudinal shield between lamps may be employed to provide at least 23-degree shielding which further reduces direct glare from the lamps. A localized general lighting system usually yields excellent results. The luminaires should be centered over the workers' side of each bench running parallel to the bench and at right angles to the normal line of sight. See Figs. 3, 4 and 6.

(b) Where the benches are located

on greater than 10-foot centers a general lighting system is desirable. This may consist of industrial luminaires mounted at least 12 feet above the floor. Where only certain benches within the area require the higher lighting levels, supplementary luminaires may be added above such benches, positioned as described above.

(c) The physical surroundings and somewhat critical tasks in the core room area warrant consideration of lighting equipment providing an upward lighting component for improved eye comfort. Since little dust is produced in core making, open reflectors are generally satisfactory. When the core room is so located that other foundry areas affect its atmosphere unfavorably, closed end reflectors with glass covers or dust-tight luminaires, or open types with vents around the top to retard dirt accumulation may be employed.

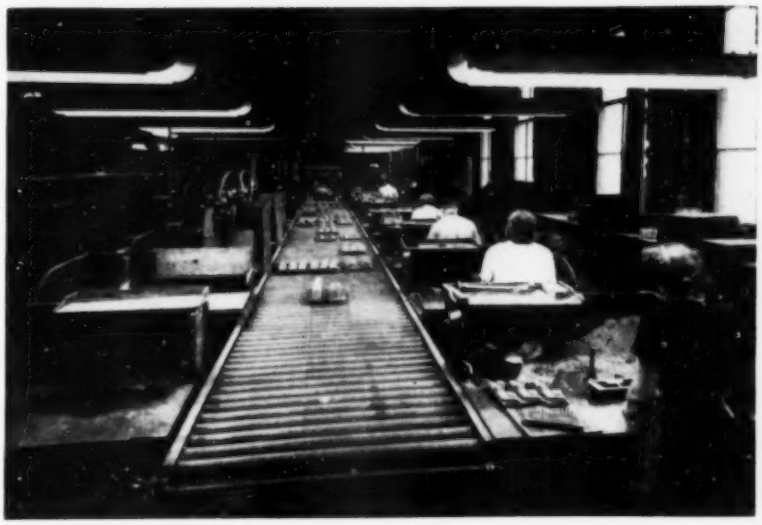


Figure 4. Core room with localized general lighting utilizing three-lamp direct fluorescent luminaires (Type B installation).

4.2—*Molding Area*

Although the great variety in product size and contour prevents exact classification of the processes of making molds, groupings can be employed on the basis of the operations performed. The first is machine molding; this usually involves small and medium-sized castings which are produced in such quantities that one or more molding machines can be operated continuously on patterns of the same general nature. The second classification is hand molding. This includes the range from small to very large patterns. Here individual molds are made, due either to the large size preventing the use of molding machines or the small volume of a given casting making it uneconomical to employ the machines. Small molds are usually made on benches and large molds on the floor. The selection of the lighting system usually is based on both the location of the task and the structural aspects of the building.

4.2.1—*Seeing Tasks* — **(a)** The sand mold is formed by packing treated sand in a flask around a pattern of the piece to be produced. The pattern is withdrawn after packing to form a cavity in the sand. Sand cores may be placed within the mold to form voids or cavities not produced by the pattern, to complete its preparation. The flask comprises upper (cope) and lower (drag) halves which, when assembled, form an enclosed cavity into which molten metal is poured. In some cases molds are built up entirely of cores.

(b) The seeing tasks involved in forming molds from treated sand are:

(1) Inspecting the pattern for foreign material.

(2) Setting the pattern in the flask and packing sand around it.

(3) Removing the pattern and inspecting the mold for loose sand and for accuracy of mold contour.

(4) Inserting core supports and cores; operator must be able to see the core supports.

(5) Smoothing mold surfaces, checking core position, and checking clearance between parts.

(c) The critical seeing tasks are:

(1) Inspection of the mold.

(2) Placing of the cores and chaplet supports, if employed).

(d) The size and detail may vary through a wide range. The smallest size has a visual angle of about 10 minutes, corresponding to the size of separate grains of sand. A defect involving the presence of only 5 or 6 grains of sand out of place will cause imperfections in small castings.

(e) The more exacting seeing tasks are repetitive, and interrupted-short-time rather than prolonged in duration. Cavities as well as three dimensional or plane surfaces are involved, so that both vertical and horizontal illumination must be provided. The contrasts are poor since the mold details and their immediate backgrounds are all dark sand, flasks and benches. The cores are usually medium brown in color giving fair contrast conditions against the black sand. Where light metal patterns are employed, a reasonable degree of contrast may exist between the sand particles and the pattern surface. The mold surfaces are dark matte. The general background brightnesses are usually low except where the dark walls of the building may have well illuminated windows in the field of view presenting a glare source on bright days. The task is usually stationary. The accuracy of the inspection is completely dependent on a quick appraisal of possible damage.

4.2.2—*Physical Characteristics* — **(a)** Most molding areas measure approximately 20 x 20 feet or larger, depending on the type of building construction and the way the bays are adapted to the molding operations. For very large molds, sections of a building 60 feet or more wide and 100 feet or more in length and served by an overhead crane may be used. Overhead obstructions usually include the sand hoppers at each molding position, the beams of low ceilings, and the crane if used for larger areas. Particularly during the winter months the atmosphere may be foggy or smoky. The walls and ceiling

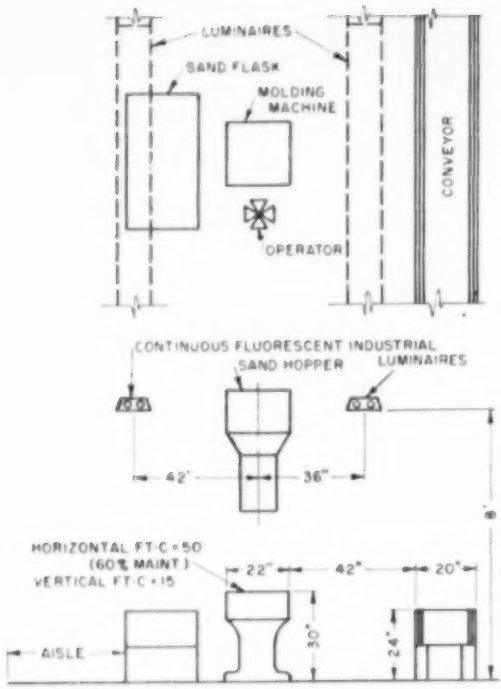


Figure 5. Molding machine area for small castings (up to 18 inches maximum dimension) with conveyor on one side and traffic aisle on the other. Two continuous rows of fluorescent industrial luminaires provide 50 horizontal footcandles maintained in service and good vertical illumination for the mold cavities.

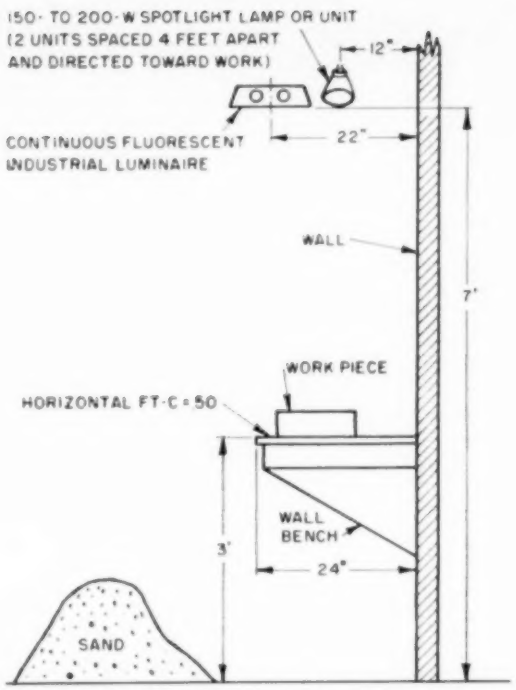


Figure 6. Lighting layout for core or bench molding along a wall. A continuous row of fluorescent industrial units mounted 7 to 9 feet above the floor directly over the molding machines or benches will provide 50 footcandles on the work. For relatively deep molds, projector spots or similar local lighting unit can be added to improve cavity lighting.

are usually a matte black or dark gray, as are the floors.

(b) The accident hazard is moderate, usually resulting from the possibility of tripping over molds, flasks or similar floor obstructions, or avoiding overhead objects, such as loaded cranes.

4.2.3—*Lighting Requirements* — The lighting is required for an intermittent task involving critical seeing of materials having low reflection factors, and brightnesses and contrasts of the most unfavorable nature. Mold cavities of various depths require good vertical illumination without harsh shadows.

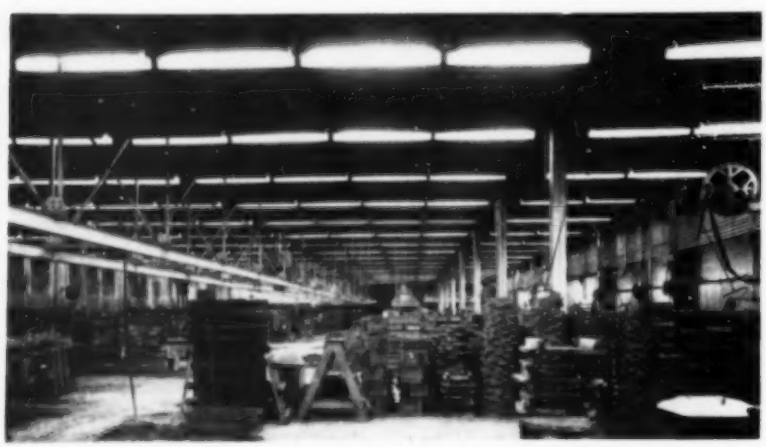


Figure 7. Medium-bay molding and pouring area illuminated by two-lamp direct fluorescent luminaires mounted 16 feet high (Type B installation).

4.2.4—*Lighting Recommendations* — **(a)** Because of the very dark surfaces and necessity of detecting small sand accumulations 50 footcandles is recommended. Fig. 5 shows a typical lighting arrangement for molding machines for small castings (up to 18 inches maximum dimension) with a conveyor on one side and traffic aisle on the other. Fig. 6 gives an equivalent layout for molders lined up along a wall. For relatively deep molds where the cavities are not well lighted by the continuous row system, individual projector spots or similar local lighting units can be located as shown in Fig. 6, to supplement the general lighting system.

(b) For the areas in which large molds are made and for which the ceiling or roof truss height may be 25 feet or greater (as well as for areas served by cranes) a general lighting system using high wattage sources such as incandescent filament or 400- to 1000-watt mercury lamps or a combination of mercury and incandescent lamps of approximately equal lumen

output to deliver 30 footcandles of illumination will meet the usual requirements. Reflectors to give medium spread rather than concentrating distributions should be employed in order that the illumination for vertical surfaces will be adequate.

(c) In high-bay wide areas where mounting height is 40 feet or greater, the 3-kilowatt mercury lamp units, with widespread distribution for vertical illumination, may be used to provide fewer lighting units for maintenance. As with all types of mercury lamps, incandescent units should also be employed to provide safety lighting immediately after a possible power interruption.

(d) Since maintenance of the lighting equipment may be more difficult under high mounting conditions, high wattage reflector bulb lamps spaced to provide the desired illumination may be used to facilitate maintenance through lamp replacement.

(e) The choice of whether high wattage incandescent alone, or the combination of incandescent and mercury, or 3-kilowatt lamp units or reflector lamps will be dictated largely by the economic aspects of initial costs, energy costs, lamp replacements and maintenance costs for each lighting system.

4.3—*Charging, Tapping, Shake-Out and Heat Treating Areas*

The seeing tasks in these areas are not exacting. The major consideration is usually safety of the worker.

4.3.1—*Charging and Tapping* — **(a)** Cupolas are charged with scrap metal, coke and limestone for melting in this area. The charging floor for the cupola is similar in most types of iron foundries. In steel foundries, open hearth or electric furnaces are used. Large and small pieces of scrap metal are handled with skip hoists, industrial trucks, cranes, charging machines or monorail system.

(b) The cupolas are usually closed with much the same materials with which the ladles are lined. The plug (in the shape of a truncated cone) is placed in position with a "batted" pole. In tapping, the plug is broken out with the pole.

4.3.2—*Shake-Out* — Castings are removed from the molds and freed of sand in the shake-out area, in the following sequence of operations:

(1) The mold is dumped on the vibrating grates of a shake-out table, or on the foundry floor.
(2) The castings are removed and placed in tote boxes, on conveyors or in some other handling device.
(3) In some cases, the workers knock the gates and risers from the castings.

The most critical seeing task is the removal of gates and risers. All seeing tasks are relatively simple, with safety the major consideration.

Figure 8. Large molding and pouring area with 1000-watt filament and 400-watt mercury lamps in enclosed dust- and vapor-tight high-bay reflectors (Type E installation).

Figure 9. High-bay general foundry area illuminated by 3-kilowatt mercury luminaires (Type F installation).

4.3.3—*Heat Treating* — Small castings are prepared for charging annealing furnaces in malleable iron foundries. These small castings are packed carefully by hand in pots so that they will not warp. Loose material is packed around these castings so that they heat evenly since fuel-fired furnaces are usually used. The main considerations of the seeing tasks are safety, and packing castings for annealing so that they will not warp.

4.3.4—*Lighting Requirements* — Current recommended practice for charging, tapping, shake-out, and heat treat-

Figure 10. Medium-bay molding and pouring area illuminated by 500-watt reflector bulb lamps (Type D installation).

ing areas is 10 footcandles maintained general illumination. Lighting for safety is a basic requirement.

4.3.5—*Lighting Recommendations* — Direct lighting luminaires of high, medium, and low bay mounting design should be used, depending upon the mounting height. The luminaires should be mounted as high as possible for worker comfort. As few luminaires of as high wattage as practical should be used in order to cut maintenance to a minimum. Supplementary lighting may be required directly over the scales. A fluorescent luminaire should be used for low mounting height.

4.4—*Pouring Area*

(a) The molds are filled with molten metal in the pouring area. The worker is forced to depend upon the light from the hot metal to see the pouring basin or sprue opening unless adequate light is provided. Pouring is done on moving conveyors in mechanized foundries, or at stationary molds on the floor.

(b) The major pouring operations in foundries are:

(1) Molds are laid in rows on the floor, or are brought into the pouring area on conveyors.

(2) Molten metal is brought into the area in large ladles by means of cranes or monorail systems.

(3) The metal is either poured directly into the mold from large crane-operated ladles, or from small manually-carried ladles which are filled from the larger.

4.4.1—*Seeing Tasks* **(a)** The most exacting seeing task is accurately directing the molten metal into the pouring basin. If the pouring basin is not hit accurately, splashing results. This splashing may push sand into the mold, causing rejects, as well as resulting in burns for the workers.

(b) The eyes of the worker have to adapt to the contrast of the bright molten metal with the dark surroundings. This affects the safety of the worker. Undue hazards, particularly from handling molten metal, may result if there are poorly lighted obstructions on the floor.

(c) The size of the pouring basin varies from a minimum of $1\frac{1}{2}$ inches in diameter to 7 inches. The seeing task is an interrupted one on a horizontal plane. The mold is made of dark sand which provides a matte finish. The sand in the pouring basin provides no contrast for the worker to see the opening. The floor of the pouring area usually provides a dark, poorly contrasting background. The sharp contrast between the molten metal and the dark background is often moderately glaring.

4.4.2—*Physical Characteristics* — The pouring area is usually adjacent to the molding area, varying from a medium to a high bay ceiling. It may also vary from a relatively small area as part of a conveyor production line to a large area covering the entire floor. Overhead obstructions are sometimes cranes or monorail systems, as well as ladles. The atmosphere is often full of smoke and steam. This makes it difficult to keep luminaires, walls, and ceilings clean.

4.4.3—*Lighting Requirements* — **(a)** Since no critical seeing tasks are present, a 10-footcandle level is satisfactory under maintained conditions. Light is required mainly for safely and adapting the eye to brightnesses which will minimize sharp contrast caused by brightness of the molten metal. Molten metal carried up and down aisles, if combined with obstructions on the floor, provides hazards. Importance is placed on keeping the aisles well lighted for safety.

(b) Uniform general illumination should be provided with a minimum of shadows and with shielding angles of at least 17 degrees for incandescent and 13 degrees for fluorescent; these shieldings are acceptable characteristics of conventional industrial luminaires. Horizontal illumination is the main consideration, with vertical illumination secondary.

4.4.4—*Lighting Recommendations* — **(a)** Direct lighting luminaires of high, medium and low bay mounting design should be used, depending upon the mounting height. The luminaires should be mounted as high as possible to keep the sources out of the normal visual field to improve worker eye comfort. As few luminaires of as high wattage as possible should be used in order to cut maintenance to a minimum. Practical maintenance considerations usually indicate the selection of filament or mercury vapor sources. Choice of luminaire type (open or enclosed) is discussed in Section 5.

(b) The low visibility of the pouring basin can be improved by placing white parting sand about the opening in order to improve the contrast and visibility. When weights are used, the opening in the weight indicates the general location of the pouring basin. This provides desirable contrast.

4.5—*Cleaning Area*

After the casting leaves the shakeout area where it has been removed from the mold it is ready for the cleaning operation in which adhering sand and any other foreign materials are removed. This operation may be

basically mechanized by the use of mechanical blast cleaning machines or tumbling barrels for smaller castings. It may be largely manual as in the use of shot or sand blast for cleaning small or large castings.

4.5.1—*Seeing Task* — **(a)** Where mechanical blast cleaning methods are used, the seeing tasks consist first, of loading the machine and second, of examining the castings to determine if they have been adequately cleaned. Where manually directed shot or sand blasts are used, the additional task of seeing to direct the blast is a factor. The only task requiring better illumination than that dictated for safety is the inspection operation. However, even this is not a severe task since very small amounts of adhering sand need not be detected. Interrupted, rather than prolonged, seeing is required. When goggles or helmets are worn, additional light should be provided to compensate for resulting obstruction of vision.

(b) Contrast conditions are fairly good during the inspection, since relatively dark sand is to be detected against the metal which has been somewhat brightened by blasting or tumbling. However, quite low brightnesses prevail in the background and surrounding areas.

4.5.2—*Lighting Requirements*—Recommended good practice calls for approximately 20 footcandles of maintained in service illumination at and about the machines. A ten-footcandle level is adequate for non-operating and traffic areas. However, where pressure blasting is conducted inside cabinets and observed through windows, or where operators wear goggles, *these values should be doubled.* Reasonable uniformity is desirable and with a general lighting system, adequate vertical illumination will result for the simple tasks. In addition, supplementary lighting through the use of units placed to illuminate loading openings and adjacent area is desirable. Conventional shielding angles of 13-degree minimum for fluorescent and 17-degree minimum for incandescent are adequate.

4.5.3—*Lighting Recommendations* — **(a)** For mechanical cleaning areas, a general lighting system of industrial incandescent or fluorescent direct luminaires should be used at moderate mounting heights. If adequate maintenance is planned and atmosphere remains relatively clear, high bay incandescent luminaires in higher areas will be satisfactory. Mercury lighting is satisfactory, but is not generally indicated unless higher than a 10-footcandle level is planned, because of resulting wide luminaire spacing with resulting objectionable shadows. Reflector lamps or angle type incandescent luminaires are desirable to provide the necessary supplementary lighting around and into the mouth of the machine.

Figure 11. Pouring molten metal into molds on the foundry floor.

(b) In blast cleaning rooms, a general lighting system is again to be desired as outlined above. However, in these areas particular attention should be given to choice of luminaires to minimize depreciation due to dirt. This is discussed in Section 5.

(c) Where blast cleaning cabinets or houses are used, the general room lighting should be supplemented by reflector lamps or by directional incandescent luminaires mounted outside the cabinet and projecting their light inside through tempered glass windows as shown in Fig. 12.

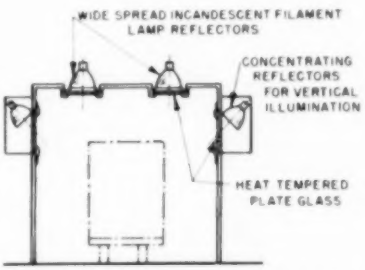

WIDE SPREAD INCANDESCENT FILAMENT LAMP REFLECTORS
CONCENTRATING REFLECTORS FOR VERTICAL ILLUMINATION
HEAT TEMPERED PLATE GLASS

Figure 12. Lighting for a sand blast house.

4.6—*Grinding and Chipping Areas*

(a) Removal of excess metal is usually accomplished by first breaking off the greater part of fins, sprues, risers and gates with a hammer; second chipping remaining projections down further with hand or power chisel; and third grinding to a finished condition. (See Figs. 13 and 15.) With quite small castings, tumbling in the cleaning operation may have removed all or most excess metal in fins, etc.

(b) Whether castings are large or small, the basic operations are the same, the difference being in whether the casting is small enough to be handled and taken to the machine, or the grinder must be taken to the casting as a portable machine.

(c) The purpose of chipping and grinding is usually to remove unwanted projections etc., but sometimes grinding is used to obtain closer tolerances on certain dimensions, flat or shaped surfaces. Disk grinding is a typical operation used, for example, to obtain a flat surface against which other parts must seat.

4.6.1—*Seeing Tasks* — **(a)** In general, the chipping operation does not entail unduly difficult or critical seeing, for

Figure 13. Foreground, chipping of castings; center, load of castings about to enter annealing furnace.

although the contrast is poor, the accuracy required is low. However, the grinding requires accurate seeing for what may be prolonged repetitive periods. The operator may have to grind to a fine scribed line, to a slipover template of a finished cast surface. Further, the casting may present a reflected glare source from specular surfaces where it has been ground, and for safety reasons the operator usually must wear goggles which may further impair his seeing.

(b) Surrounding conditions will vary depending on operations being conducted in adjacent areas, but in general they are about average industrial conditions typical of heavy industry, with dark ceiling, floors and walls interrupted by unpleasantly bright windows.

4.6.2—*Physical Characteristics* — Grinding and chipping areas are likely to exceed 20 feet in minor and 50 feet in major dimension and may have heights of anywhere from 10 feet to 50 feet, although of course higher ceilings occur only where convenience dictates choice of such an area. Overhead obstructions may be considerable in the form of grinder supports, exhaust hoods, cranes, etc. Atmospheric conditions are fair.

4.6.3—*Lighting Requirements* — **(a)** Tasks of the nature of chipping require approximately 30 footcandles of maintained-in-service illumination so arranged as to produce uniform horizontal and vertical illumination.

(b) Ordinary grinding will require at least 30 footcandles. Accurate grinding will require an additional 50 footcandles, usually provided by supplementary lighting. Large castings finished by portable or swing grinders require particularly good uniformity in the area with adequate light on vertical as well as horizontal surfaces.

4.6.4—*Lighting Recommendations* — **(a)** In areas devoted solely to chipping and removal of gates, fins, risers etc., a general lighting system utilizing industrial incandescent or fluorescent luminaires should be used in low bay areas. Where mounting heights are greater than about 20 feet, high and medium bay luminaires (incandescent and/or mercury vapor) are indicated. Selection of luminaire distribution and lamp sizes should be such as to give uniform horizontal coverage with adequate overlap so that vertical illumination is maintained. Luminaire location should be such that shadows of the worker are not cast in the work area.

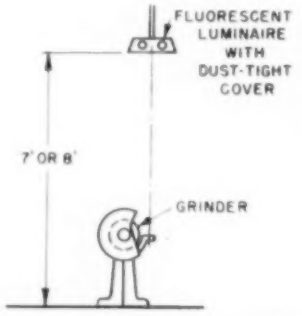


Figure 14. Lighting for a stand grinder.

(b) A general lighting system similar to that described above is also desirable for areas where swing grinders or portable hand grinders are used. However, a larger number of luminaires and/or larger lamp sizes are required to provide the higher lighting levels recommended. If large castings in these areas are repeatedly placed at the same location for grinding with these movable machines, a localized general lighting system of fluorescent luminaires may be applied economically with the bulk of the luminaires concentrated above grinding locations.

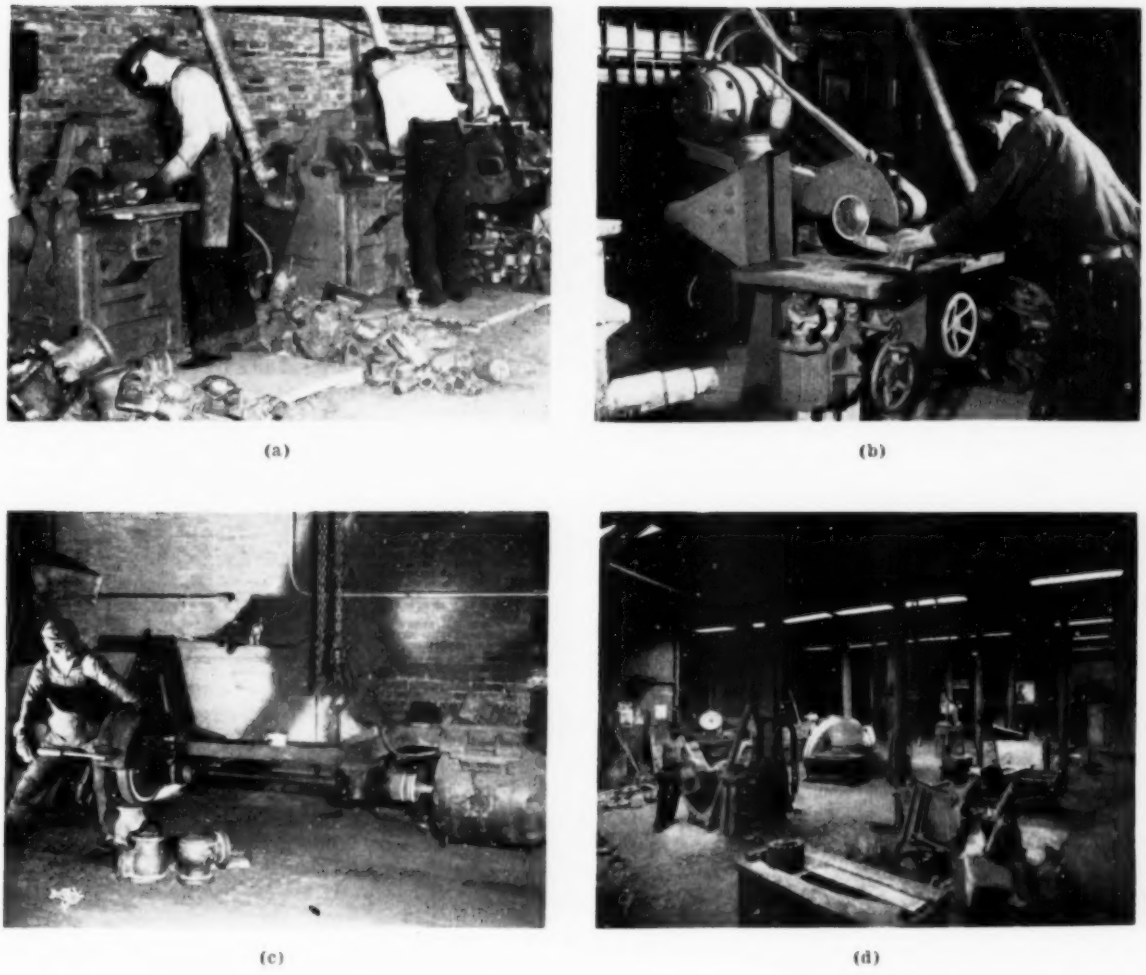
(c) Where permanently located grinders are used for the finishing of smaller hand-held castings, either a general plus local lighting system or a localized general system may be adopted. A satisfactory location of a supplementary luminaire is shown in Fig. 14.

(d) In all grinding areas, large area low brightness luminaires employing fluoresent lamps are preferable to incandescent or mercury because of the specular nature of the ground surfaces and because each grinder may perform inspection operations in the normal course of his work.

4.7—*Inspection and Sorting Areas*

(a) In a foundry as in many high production industries, inspections are generally conducted at many intermediate stages in the production of the complete product. In foundries the inspections at some stages are either combined with the particular operation or at least performed in the same immediate area. Where this is the case, the inspection task will dictate the necessary quality and quantity of illumination.

(b) Typical of these conditions is the inspection of cores by the coremaker prior to baking. Similarly, pieces may be scrapped by the shakeout handlers or by grinder operators,



(a) (b) (c) (d)

Figure 15. Cleaning and grinding: (a), (b) and (c) — close-ups; (d) low-bay area illuminated by three-lamp enclosed direct fluorescent luminaires (Type B installation).

thus saving subsequent labor on defective parts. Sorting is frequently combined with inspection of small castings.

(c) As in any industrial inspection task, classification may be made along lines of precision of workmanship required in the finished part. The generalization may be made that extreme precision is more likely to be required in medium and small castings.

4.7.1—*Seeing Tasks* — **(a)** The operations involved in sorting are simple visual recognition of different castings so that they may be segregated into proper bins, barrels etc. The visual task is repetitive, but not at all severe.

(b) Inspection of the product, on the other hand usually entails a more severe visual task even with rough castings, since cracks, small missing projections, corners etc., small defects and surface imperfections must be detected. With small parts the task is highly and rapidly repetitive.

(c) Contrast conditions on the part itself are usually poor, and surrounding conditions may be poor to fair depending on the degree of atmospheric cleanliness attainable. In some cases medium large castings such as automotive cylinder blocks require minute scrutiny of cored holes and passages with a view to maximum precision.

4.7.2—*Lighting Requirements* — **(a)** For separately located sorting operations, the amount of light required will vary directly with required speed and inversely with casting size. Levels of 10 footcandles are satisfactory in most cases, with a general lighting distribution and no particular emphasis on vertical illumination.

(b) For inspection areas the following levels are current recommended practice:

Class of Inspection	Footcandles Maintained in Service
Medium	30
Medium fine	50
Fine	100

(c) In general, a high degree of horizontal uniformity is desired, together with adequate wide beam spread to provide vertical illumination. Shadows must be minimized and large area luminaires are desirable. Sometimes portable hand lamps are required for inspection of cavities in very large castings. Because of the relatively high

level required for medium fine and fine inspection, localized general or local lighting systems are normally indicated, the former where inspection is part of a larger area.

4.7.3—*Lighting Recommendations* —

(a) In sorting areas, a simple general lighting system of industrial luminaires may be mounted 4 or more feet above the sorting table or conveyor. Type of equipment (open or enclosed) will be dictated by atmospheric and maintenance conditions.

(b) For "medium" inspections, general lighting systems will also suffice. Fluorescent luminaires may be used for reduced reflected glare and improved diffusion of light.

(c) "Medium fine" and "fine" inspection on the other hand sometimes require special lighting treatment. A criss-cross grid of fluorescent luminaires will provide maximum diffusion, eliminate shadows, and build up the level of illumination. This arrangement also assists in lighting cavities etc. Mounting height should be 5 or more feet above the inspection work level.

(d) The physical surroundings and somewhat critical tasks in this inspection area warrant consideration of luminaires providing an upward component for improved eye comfort.

4.8—*Storage and Warehousing Areas*

In general, no exacting visual tasks are involved in foundry storage and warehousing areas. Material awaiting shipment is often temporarily stored on the open floor, and general illumination from conventional industrial filament or fluorescent units to provide 10 footcandles (maintained in service) meets the task requirements. For material stored in bins, which may be either the product awaiting shipment or more usually patterns or spare parts, illumination of the bin interiors and the aisles is best accomplished with fluorescent single lamp trough reflector units installed in a continuous row extending along the full length of the bins and aisles. It should be located as low as practicable, usually at the height of the top level of the uppermost bin, in order that as much light as possible will reach the insides of the bin spaces. Special stock bin and aisle lighting units, designed to distribute light as evenly as possible from top to bottom on the face of shelves, are also available.

4.9—*Shipping and Receiving*

(a) In the shipping and receiving areas, the most difficult visual tasks consist of making out shipment forms, checking labels and materials, and in some cases, of packing. General illumination of a maintained-in-service level of 30 footcandles minimum is recommended. Conventional industrial units of either the filament or fluorescent lamp type may be employed, as covered in Table I.

(b) If fluorescent lamp units are employed, a continuous row installation can be made with every other unit omitted and spacing between rows to give the desired footcandle levels. This provides flexibility in case the area should be used for production operations. Then, for production, an equal number of units can be added at minimum cost to provide double the illumination level in line with the production operation requirements. The physical surroundings and somewhat critical tasks in the shipping and receiving areas warrant consideration of luminaires providing an upward lighting component for improved eye comfort.

5. Maintaining the Lighting System

(a) The presence of dust, dirt, fumes, and moisture result in lighting equipment and lamps getting dirty in a short time. Thus, the levels of illumination obtained with a new lighting system do not prevail for long, and periodic cleaning should be provided. In any case, the maintenance factors to be used in calculation of a satisfactory foundry lighting system are lower than for most industrial work areas.

(b) Particularly in the melting, pouring, and cleaning areas, the illumination level may be reduced by 40 per cent in a 3-month period. In foundries where periodic maintenance is not the practice, it is not uncommon to find that the footcandle levels have dropped to less than one-half of those obtained when the lighting system was new. A schedule for periodic cleaning of the lighting equipment should be set up. This should not be less than every four months for the areas just mentioned where the most unfavorable conditions exist, and at least every six months for the other areas. Even these cleaning intervals are not as frequent as can usually be justified on the basis of obtaining the most light at the lowest unit cost. This holds true since the basic investment, energy and lamp costs continue at the same rate even though the illumination is greatly decreased due to the accumulation of dirt on the lamps and reflectors.

(c) It will be found that for many medium and high-bay areas, the use of disconnecting hangers will lower cleaning costs by reducing the time required to get at the unit for cleaning and avoiding the necessity for tying up a crane for getting at the high mounted units. The disconnecting hangers practically eliminate the accident hazards since cleaning can be done at floor level.

(d) Particularly with the fluorescent lamp equipment, group replacement can be tied into the cleaning schedule. This is desirable since many lamps will continue to operate even though the light output has been reduced to 70 per cent or less of the initial value, due only to depreciation in the lamp, independently of the effect of dirt accumulation.

(e) Particularly with the higher wattage lamps used in high bay areas, a ventilated type of reflector and lampholder assembly will provide improved maintenance; in extremely dirty locations the enclosed dust tight equipment may be desirable. Reflector bulb lamps may be used to facilitate maintenance of light output through lamp replacement without conventional cleaning.

I.E.S. Emblem

The official emblem of the Illuminating Engineering Society is available to members in 14 karat gold, lapel screw back buttons, in the miniature ½" size, at only $3.50 each including taxes. Blue background for Members, red background for Associate Members. Order from the Illuminating Engineering Society, General Office, 1860 Broadway, New York 23, N.Y.

T E L E C A S T
LIGHTING NEWS OF CURRENT INTEREST

Dallas Is Host to I.E.S. Council at April Meeting

Council went "on the road" so to speak, for its April meeting, held April 13 at the Baker Hotel, Dallas, Texas. Purpose of its southwestern site was to afford easier opportunity to western and southern members to attend. So successfully was this purpose met that serious consideration will undoubtedly follow for annual meetings in the south or west. Another benefit was the opportunity, in many cases for the first time, for local officers from the Southwestern Region to observe the national body in action. W. E. Folsom, Regional V P. voiced the welcome to Council from his Region and particularly from the large delegation of Texas and Tulsa members attending the meeting.

Filling the conference room were some 41 including the following: President E. M. Strong presiding; and Past President Walter Sturrock, Ralph Heitzman proxy for S. G. Hibben; R. L. Biesele, Jr. proxy for Vice President Duncan M. Jones; C. A. Patterson proxy for C. C. Keller, General Secretary; Treasurer Kirk M. Reid; Directors Charles R. Long, J. F. Whitehead, Jr., F. C. Winkler, F. A. Covington proxy for G. W. Beals, P. M. Rutherford proxy for Roy A. Palmer, M. J. Myers, proxy for J. S. Schuchert; Regional Vice Presidents Harold T. Rankin, L. B. Paist, George J. Taylor, R. Cecil Paslay, L. A. Hobbs, W. E. Folsom, W. G. Darley, proxy for L. C. Twichell, V. J. Graham, proxy for Walter J. Lind; Executive Secretary A. D. Hinckley; Technical Director C. L. Crouch and Editor Ruby Redford; L. J. Anderson, Lena May Aulauf, Lee Collins, Jr., John Deck, A. N. de'Espenza, John Felton, B. L. Guess, Jr., Elmer E. Hyden, W. T. Kimery, R. K. Lothrop, T. Lynn, H. F. Miller, W. F. Owens, Jr., Ruth Patterson, N. O. Reed, E. S. Richardson, S. S. Rutledge, T. C. Sargent and H. D. Weisser.

Following regular Council action with regard to approval of previous Minutes (items of which were discussed in detail), finance and other business, Council approved a resolution on its recent loss in the death of A. C. Bergh, for many years Miami's most active member (see I.E., April 1953, p. 15A).

Membership Statistics

The report of the Board of Examiners as made for Clifford Miller, Chairman, by Executive Secretary A. D. Hinckley, announced the election of 113 Associate Members and 9 Students. The Board further recommended Council election of 23 Members. Lists of all April elections by Section and Chapter are given elsewhere in this issue. Favorable action of Council on the report, together with other membership changes results in the following membership figures:

September 30, 1952		April 13, 1953
7394	Total Membership	7951
34	Members Emeritus	33*
41	Fellows	58
1797	Members	1872
5293	Associate Members	5675
229	Student Members	293

*Includes 12 Fellows.

Mr. Hinckley also reported for the Membership Committee, R. G. Slauer, Chairman, giving a detailed analysis of membership activity in comparison with the past two years at this time of year.

New Sustaining Members

Four new Sustaining Members were elected, on the recommendation of C. C. Shotwell, Chairman. These are:

Progressive Products Co. Inc.
6615 Milwaukee Avenue
Chicago 31, Ill.
Official Representative — E. George Goddard

Pryne & Co. Inc.
P.O. Box 698
Pomona, Calif.
Official Representative — Roger W. Holston

Super Electric Construction Company
4300 W. Chicago Avenue
Chicago 51, Ill.
Official Representative — P. M. Pavesich

Terreau Racine Ltee.
190-228 St. Paul Street
Quebec, Que., Canada
Official Representative — Paul Ducasse

Publications

In the absence of Duncan M. Jones, Chairman, Ruby Redford, I. E. Editor, reported to Council on the Society's publication program. She outlined the financial status of the program to date, indicating a sound financial operation for the publication, and reported editorial plans for the next several issues of the magazine. A plan for Conference Preprints, this year the financial responsibility of the Publications Committee, was reported in a letter from Mr. Jones. Preprints are expected to be made available to Conference delegates at a price of $2.00 per set. Further study will be

COUNCIL MEETING in Dallas gives western and southern members an opportunity to see the national governing body in action.

made leading to a recommendation on future policy.

The Committee reported that large I.E.S. and publication display panels will be sent to each Regional Conference, and that 10 portable display cases are being built for use by Sections and Chapters. This program has been developed by the Committee to inform all members on the availability of the Society's latest literature.

Status of the *I.E.S. Lighting Handbook* pointed to a need for reprinting by the end of the year, with a steady distribution of about 150 books per month.

Local Activities

Projects under way in a number of localities were reported by Mr. Hinckley for Duncan M. Jones, Local Activities Chairman. Some of these included an I.E.S. sponsored vision conference at the Rochester Institute of Technology; Student Membership Awards at the Michigan State College organized by Michigan Section of I.E.S.; an active Study Club at La Crosse, Wisconsin; enthusiastic contests for "My Most Interesting Lighting Job" held by 25 I.E.S. Sections and Chapters; large lighting conference conducted by G. W. Frederick, Local Representative in Sioux Falls, South Dakota.

Professor Strong reported to Council on highly successful Regional Conferences held in Ottawa, Portland and Los Angeles, and also of a well organized and well attended I.E.S. meeting in Pueblo, Colorado, of Regional Conference calibre. He indicated that the fine spirit of members in San Diego, Calif. and several large meetings held this year, foresee the formation soon of a new Chapter in that territory.

Each of the Regional Vice Presidents (or their proxies) reported separately at this point, on activity in his Region. A number of suggestions and good ideas for procedure were exchanged during general discussion of successful practices. The discussion was especially valuable, involving as it did, a number of officers who cannot attend Council frequently.

Recommended Practices

The new Recommended Practice for Home Lighting, presented by Kirk Reid for Mary E. Webber, Chairman, was discussed in detail and approved for letter ballot. The new Practice sets basic standards for home lighting and includes full explanation of its meaning in application.

A report recommending lighting for Central Station High Bay Areas was discussed, and returned to committee for further study.

A revised Guide for Testing Procedure was given tentative approval subject to consideration and signature of the entire committee, four votes being absent from the report.

Technical Report

C. L. Crouch, Technical Director, outlined in detail work progressing in the Society's Technical Committees. Several full day and/or two day meetings were reported for the Coordinating Committee for Defense, the Color and Illumination Committee, Light Sources, Maintenance Committee, Street and Highway Lighting, Hotel Lighting, Public Conveyances Committee and others.

He noted that the Fog Lighting Committee had been requested by the New Jersey Turnpike authorities to make a study and recommendation on visibility in fog. Additional official interest in I.E.S. services was indicated by: Distribution by the U. S. Labor Dept. of the new Industrial Lighting Practice; ditto of I.E.S. Office Lighting Practice by the National Office Management Association; communication from the U. S. Army expressing confidence in I.E.S. standards and request to reprint; request from the Armed Forces to attend New York Conference sessions.

The report on the Southwestern Regional Conference, which followed Council Meeting in Dallas, April 14-15, will appear in the June issue of I.E.

All Canadian Chapters Represented At Regional Conference in Ottawa

The attendance figures for I.E.S. Regional Conferences, and especially widespread region representation, become headline news as these Conferences assume more and more the importance of national meetings. In the Society's Canadian Region, as well as others, this annual meeting is The Convention. At Ottawa, March 23 and 24, sessions with well organized discussion periods featured valuable papers, and they don't mean "talks." Advance copies of papers were included in the delegates' envelopes. Planning there starts a year, or even more, ahead of the event and the Convention Committee each year lines up the highest local talent available. Plans for a three day convention in Toronto in 1954 got under way before the Ottawa meeting even started, with next year's dates all set.

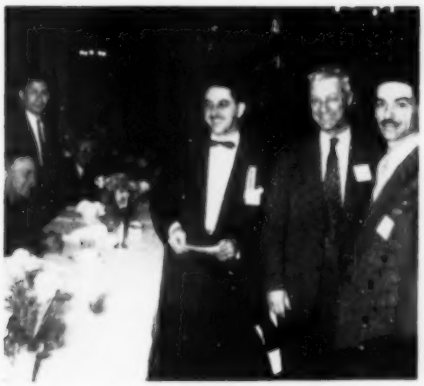
There is an undeniable flavor to Canadian meetings—a refreshing one to most American visitors—of which there were eight in Ottawa (see box score). To attempt to define it risks describing only a "part of the elephant." Whatever it is, it adds so materially to the importance of the event, and to the gaiety of the social program, some mention is in order for any conscientious coverage of a Canadian Convention. A Conference site like the Chateau Laurier adds something, to be sure.

Perhaps part of the flavor is in the several "foreign" papers usually presented. At Ottawa, two such were included, both from England. Street and Highway Lighting was seen in an entirely new light (literally as well as figuratively) when W. F. B. Debenham from General Electric, London, stepped to the

DISCUSSION period during a technical session at the Canadian Regional Conference.

At the Canadian Regional Conference

J. W. Bateman, of the Toronto Section, is being congratulated by Professor E. M. Strong, I.E.S. President, on his recent election to the grade of Fellow of the Society.



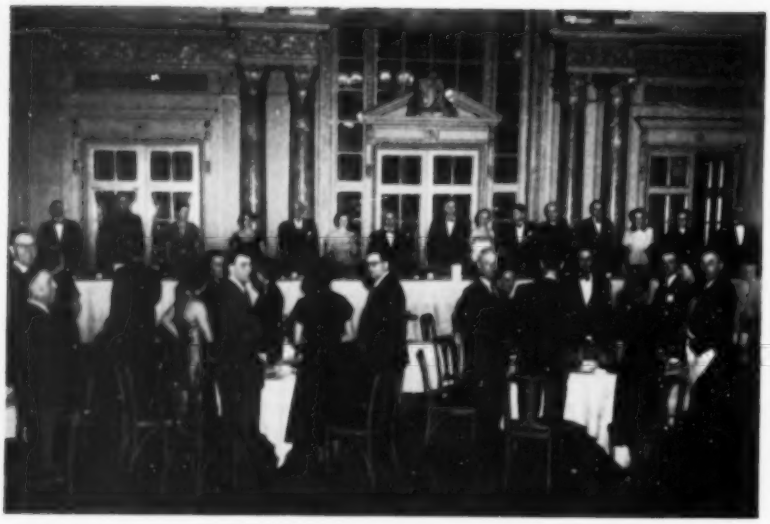
Winners of the contest, "My Most Interesting Lighting Job," in the Canadian Region are: tie for second place, W. E. Reny and Romeo Martineau; first place, Benoit Doucet.

W. F. Nottelman, Toronto Section; T. D. Wakefield, from the Cleveland Section; F. W. New, Hamilton Ontario Chapter, and W. E. Dalrymple, Toronto Section, talk over some no doubt weighty matters.

Four R.C.A.F. people get together at the Conference: r. to l., H. J. Goodenough and J. H. Rylance, civilians attached to the Air Force; and W.O.2 R. G. Stewart and F/O J. McDonald.

Inter-Section discussion is held by George Watters, Quebec Chapter; J. J. Dawson, Hamilton Ontario Chapter; Joseph Thomas, Montreal Section; and J. R. Lalonde. All Sections and Chapters were represented at the Conference.

I.E.S. V.P Duncan Jones; J. H. Rylance, past chairman of the Ottawa Chapter; W. J. Montabone, Conference Chairman, and F. C. Mayberry, chairman of the Toronto Section as seen at the Canadian Regional Conference.



STANDING at the head table at the banquet March 23rd are: A. D. Hinckley, Executive Secretary, I.E.S.; Major G. D. Mills, Chairman, Ottawa Chapter; Mrs. D. M. Jones; Mrs. W. J. Montabone; S. G. Hibben, Past President; Mrs. F. P. Labey; E. M. Strong, President; F. P. Labey, Canadian Regional V-P; Mrs. E. M. Strong; W. J. Montabone, Conference Chairman; Mrs. S. G. Hibben; D. M. Jones, Vice-President; Mrs. G. D. Mills; Miss Ruby Redford, Editor, ILLUMINATING ENGINEERING; and M. B. Hastings, nominee for Canadian Regional V-P.

Attendance
Canadian Conference

Toronto	55
Montreal	46
Ottawa	43
Hamilton	9
U. S.	8
Quebec	6
Winnipeg	3
Maritime	2
Total	172

stage. Spurning such mechanical aids as microphones, Mr. Debenham amused as well as educated the gathering. Apparently shipped all the way from England were several actual street lighting units (shall we say "fittings"?) which attracted considerable interesting during recess.

Another overseas speaker was Allen H. Owen, Vice-President of the British I.E.S. Mr. Owen may be remembered by many members from the New Orleans national conference in 1947. In Ottawa he spoke on Blackout Lighting, a serious business when needed.

The Military, and Government, also appeared on the program in the persons of C. F. Pattensen, National Research Council; T. J. Brant, Approvals Laboratories Division of C.S.A.; W. A. Ramsey, Air Service Branch, Department of Transport; and Vice-Marshal H. B. Godwin, Royal Canadian Air Force. AVM Godwin addressed a luncheon meeting the last day of the Conference.

M. M. I. L. J.

Canada entered the Inter-Region contest for "My Most Interesting Lighting Job" this year. While not all Sections and Chapters within the Region participated, the three who did presented unusually interesting jobs, with two tying for second place. First prize was won by Benoit Doucet (Curtis) for Montreal Section. M. Doucet will compete with his entry against the other Regions in New York next September. Tied for second were William Reny, Northern Electric Company Ltd. for Ottawa Chapter, and Romeo Martineau, La Cie Martineau Electrique Ltee for the Quebec Chapter.

Social Program

A very hospitable Reception Committee saw plenty of action in Ottawa. In addition to the luncheon meeting, which was a joint affair, a planned program for visiting ladies included a tour of the Parliament Buildings, a trip through the Mint, and inspection, followed by lunch, at the Brading Brewery plant.

Highlight of the social program was, of course, the President's Reception and Banquet and dance, honoring President and Mrs. Everett M. Strong. Professor Strong was the featured speaker at the Banquet. In addition to his address, President Strong officiated also at a ceremony during the banquet, presenting the white Fellow lapel pin to J. W. Bateman of Toronto, recently elected a Fellow of I.E.S. Mr. Bateman is the third Canadian to be so honored, the other Fellows being R. M. Love and G. F. Mudgett.

Professor Strong was on the receiving end of a presentation also. Ottawa Chapter presented him with a most interesting sculpture—a moose carved entirely from a single log.

Ideas Worth Stealing

1. Mimeographed copies of papers, distributed in advance of the technical sessions.

2. Host Chapter's Charter suspended in front of the speakers' rostrum.

3. Ticket books with detachable tickets for each event, making nose-counting easy.

4. At the President's Reception, a prize was awarded to the fifth man and fifth lady to shake hands with "Mr. X." In the effort to discover the mystery man, ice was broken and many hands shaken all round.

5. Local Activities meeting held the evening before the Conference, with Regional Veep, Frank P. Labey presiding.

Credits

Conference personnel responsible for the successful meeting included:

Regional Vice-President—F. P. Labey, Northern Electric Co., Ltd.
Conference Chairman—W. J. Montabone, Ahearn & Soper, Ltd.
Papers—J. H. Rylance, Canadian Department of National Defence.
Finance—W. E. Reny, Northern Electric Co., Ltd.
Registration—W. B. Fulton, Northern Electric Co., Ltd.
Entertainment—M. J. Cote, Canadian Westinghouse Co., Ltd.
Publicity—A. S. Kennard, Canadian General Electric Co., Ltd.
Transportation—L. C. Dupuis, Canadian Westinghouse Co., Ltd.
Hotel Accommodation—J. G. L. Walden, Department of Veterans Affairs.

Technical Program

For the record, the papers program in its entirety was:

Morning Session, March 23

Conference Opening—Frank P. Labey, Canadian Regional Vice-President, Northern Electric Co.
Address of Welcome—Controller Paul Tardiff, representing Mayor Charlotte Whitton.

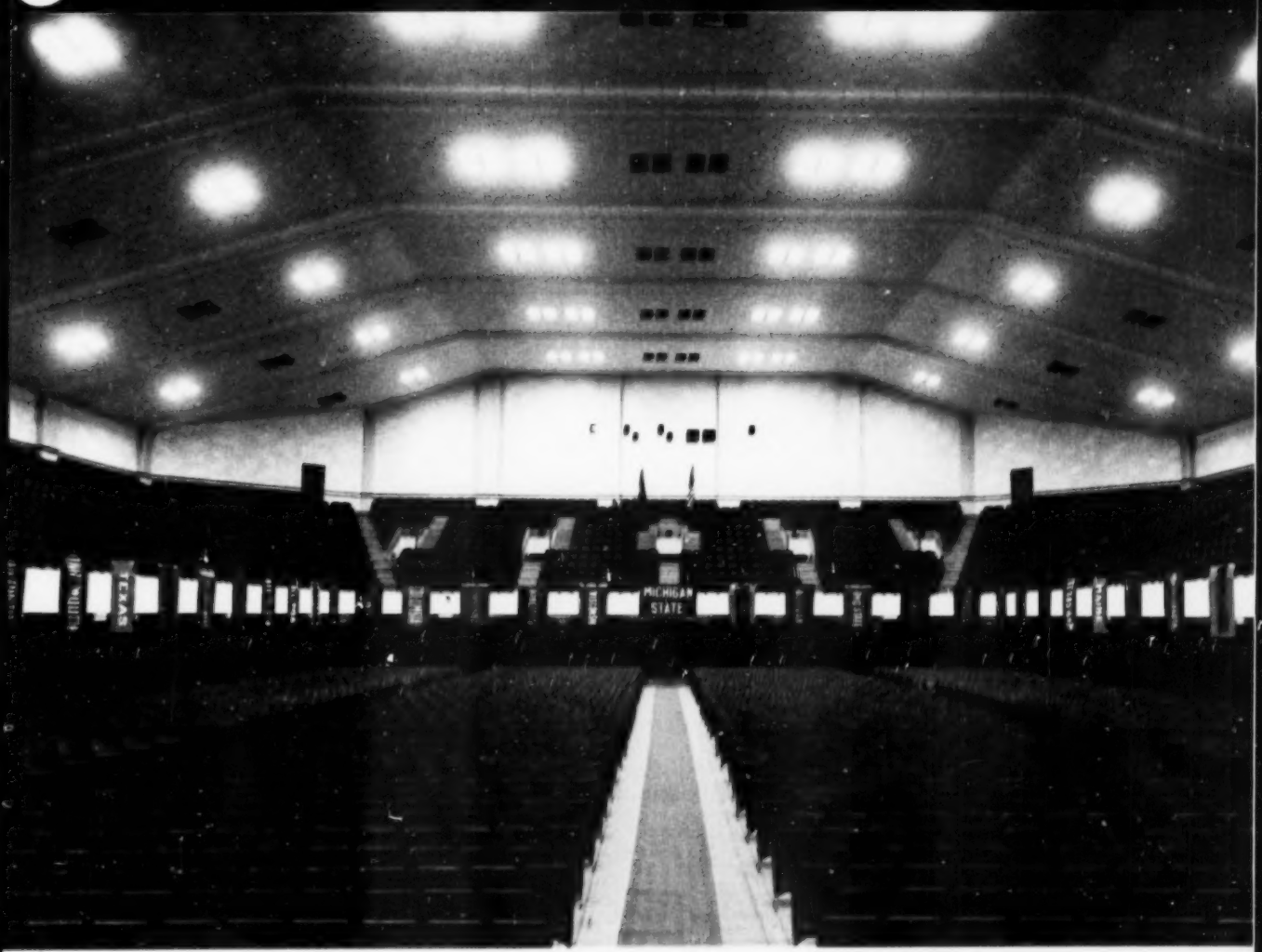
(Continued on page 12A)

Photo Credits

Acknowledgment and thanks is made to D. F. Knudsen, Editor of *Electrical News and Engineering*, and to E. Victor Manser, Editor of *Electrical Digest*, both of Toronto, for photographs taken at the Canadian Regional Conference.

KIRLIN - A. I. Architects file, 31 F.

KIRLIN *Recessed* LIGHTING



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due to Alzak glass-surfaced aluminum reflectors and KIRLIN prism lens.

There are many advantages when the Kirlin Method is used. There is more useful light from the lamps—a wider distribution of light rays—fixtures can be re-lamped from above the ceiling. Lighting maintenance costs are less.

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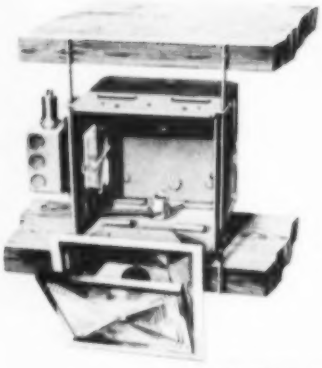

Installation costs are less with Kirlin fixtures. Regular building wire, such as rubber covered, is run direct to exclusive heat-insulated junction box. No asbestos wire is needed.

- Made in all sizes—square or rectangular—and in Fluorescent.
- Hinged rust-resisting doors in die cast frames suitable for outdoor locations.
- Wide-angle or concentrating lens.
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- In stock at leading wholesalers.

Installed cost is less than cheap units!

WITH THE Kirlin METHOD NOTHING DANGLES FROM THE CEILING TO COLLECT DUST, AN IMPORTANT FACTOR IN THE HOME OR OFFICE AS WELL AS IN PUBLIC BUILDINGS.

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Designed to replace the light switch in a wall . . . to permit the selection of any light value from blackout to full brightness, the WALLBOX Dimmer offers a new concept in lighting control. By simply turning a knob, light just right for every occasion, any activity, is at your finger tips. It is a transformer. . . cool, efficient and economical in operation . . . controlling by converting watts. Unlike resistance type controls, it does not dissipate power dangerously and wastefully in the form of heat.

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BRISTOL, CONNECTICUT

(Continued from page 8A)

TECHNICAL SESSION
Fred C. Mayberry (Toronto Section), Chairman

Radio Interference—C. F. Pattenson, Head, Instrument Section, National Research Council, Ottawa, Ont.
Testing and Certification of Luminaires—T. J. Brant, Supervising Engineer, Approval Laboratories, C.S.A., Toronto.

AFTERNOON SESSION, MARCH 23
Rolland Webb (Maritime Chapter), Chairman

My Most Interesting Lighting Installation contest.
Street and Highway Lighting—W. F. B. Debenham, General Electric Ltd., London, England.
Blackout Lighting—Allen H. Owen, Vice-President of the British Illuminating Engineering Society, Manchester, England.
Reception of I.E.S. President E. M. Strong. Speaker, Professor Strong.

MORNING SESSION, MARCH 24
R. S. Tate (Montreal Section), Chairman

Modern Hospital Lighting—D. W. Heywood, McDougall & Friedman, Montreal.
Influence of Modern Illumination on Architecture—W. A. Ramsay, Chief Architect of the Air Service Branch, Department of Transport, Ottawa.
Airdrome Lighting—L. C. Simpson, Vice-President, American Gas Accumulator Co., Washington, D. C.
Luncheon — Chairman, W. J. Montabone. Speaker, Air Vice-Marshal Godwin, Commanding Air Material Command, Ottawa.

AFTERNOON SESSION, MARCH 24
Alex de Lery (Quebec Chapter), Chairman

Let's Understand Each Other—Dr. S. G. Hibben, Director of Applied Lighting, Westinghouse Electric Co., Bloomfield, N. J.
Lighting for Defence and Production—R. P. Lindsay, Canadian Line Materials Ltd., Toronto.

Seminar Given by Michigan Section Promotes Student Participation

To stimulate student interest in the Illuminating Engineering Society and its objectives, and to encourage student presentation of papers, the Michigan Section sponsored a Student Seminar at the University of Detroit, March 19. Presentation of the program was directed by Professor Walter Hedrich, Chairman, and Professor Edward L. Fairchild, Educational Student Membership Committee of the Section.

A total of 55—45 students and ten practicing engineers—attended the all-afternoon program which included:

"Dimming of Hot Cathode Fluorescent Lamps," by Eugene Foley, student at the University of Detroit.
"Seeing with Light," by L. E. Tayler, Detroit Edison Co.
"Light Sources," by Ted Brown, General Electric Co.
"Architecture and Its Relation to Lighting," by Professor T. S. Tanner, University of Michigan.

Mr. Foley was awarded a copy of the *I.E.S. Lighting Handbook* for the presentation of his paper.

There were five representatives officially representing the universities and colleges at this meeting: Walter Hedrich, University of Michigan; Edward L. Fairchild, Wayne University; Donald E. Trefrey, Detroit Institute of Technology; Louis Kormendy, University of Detroit; and Elwyn Hancock, Lawrence Institute of Technology.

The success of this first Student Seminar has encouraged the Section to make it a yearly occurrence.

Light's Diamond Jubilee Plans Underway with E.E.I.

Preliminary work on programs and materials for next year's Diamond Jubilee of Light has been initiated, following approval of Jubilee aims by the Edison Electric Institute Board of Directors, it has been announced by George H. Blake, Chairman of the Jubilee Program Planning Committee.

In paying tribute to Thomas Edison's invention of the first practical incandescent electric lamp which launched the electric era in 1879, the Jubilee will also give attention to the growth and progress resulting from its subsequent development.

Under the Planning Committee, and representing a wide range of electrical industry interests, is a Jubilee working committee which will develop programs and materials and make them available to electrical companies. To be observed on a national and local scale, Light's Diamond Jubilee will enlist the cooperative efforts of utilities, manufacturers and other interested electrical groups, with particular emphasis on activities conducted by local companies in their own communities.

CHARTER NIGHT at the Twin Ports Chapter had an attendance of 40 members. At the head table are r. to l.: Morris Braden, Honorary Twin Ports Chairman; L. J. Riegert, Past Chairman of Twin City Section; J. L. McEachin; Donald P. Greene, Chairman of the Twin City Section; George B. Spurbeck, Chairman of the Twin Ports Chapter.

These Sections Had a Good Idea

Three or four "good ideas," unusual or especially successful local projects, undertaken by I.E.S. Sections or Chapters will be outlined here each month. —ED.

1. The **Cornhusker Chapter,** Omaha, and the **Iowa Section,** Des Moines, have for a number of years conducted their meeting programs on the unique plan of holding four major conferences per year instead of regular monthly meetings. These meetings usually begin with a luncheon, present a full afternoon program of speakers, and an evening dinner with occasionally an after-dinner speaker. The arrangement has solved the rather unusual territory problem existing there. In the Cornhusker Chapter for instance, membership is almost entirely in Sioux City, Omaha and Lincoln with a few members in Columbus, Nebraska, a membership scattered in a 100-mile radius. Several Study Clubs have been

(Continued on page 17A)

Here and There with I.E.S. Members

Dinner meeting of the Mexico Chapter, March 13, at which ten new members were welcomed. At right, retiring Chairman Jose Carlos Silva hands the gavel of office to incoming chairman Antonio Carbajal.

Members of the Utah Chapter at their February luncheon meeting. B. D. Levaur, Pittsburgh Reflector Co., was guest speaker and discussed store lighting. Chapter Chairman L. M. Slusser presided.

Before dinner at the March 20 meeting of the St. Louis Section, Section Chairman L. M. Wallace (left), chats with guest speaker, J. H. Jensen, Residential Lighting Specialist, Gneral Electric Co., and Lester C. Haeckel, President of the St. Louis Chapter, American Institute of Architects, who attended the Section meeting.

Winners of the Southern California Section's contest, "My Most Interesting Lighting Job," March 4, are, l. to r.: Oscar W. Meissner, Los Angeles Department of Water and Power, first place; Harold F. Hall and Richard B. Hatfield, of Southern California Edison Co., second and third places, respectively.

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for architects in planning fluorescent lighting

three ways to install

1. recessed. Only the luminous Plexiglas is visible, depth 2½" from ceiling line.

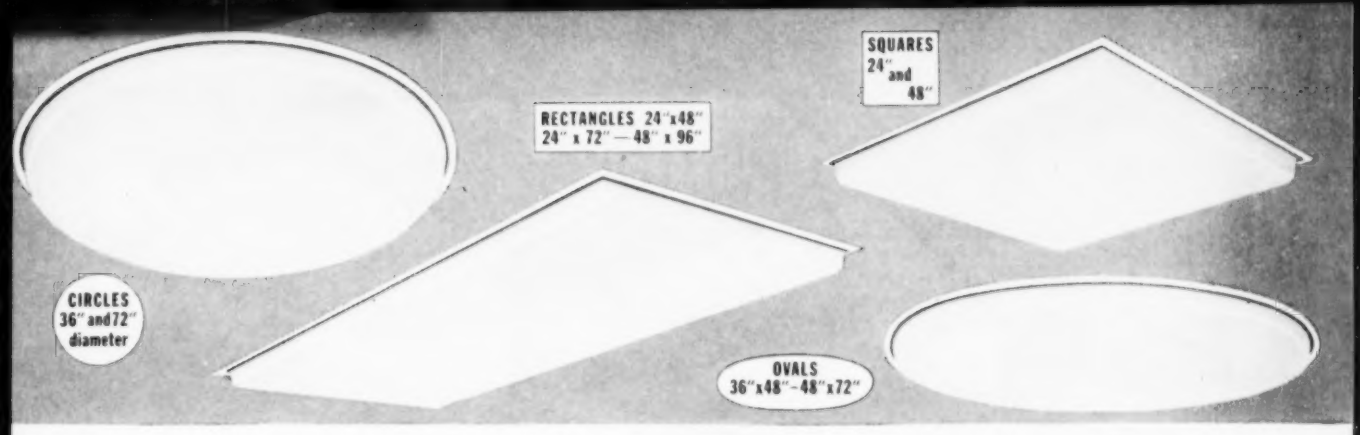
2. surface-mounted. Variform luminaires hug the ceiling and blend in harmoniously. Depth only 6¼" from ceiling line.

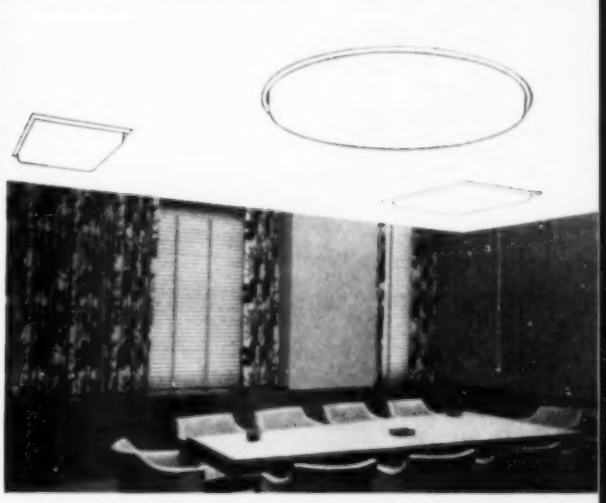
3. suspension-mounted. Hangers can be placed to give perfect support to even the largest fixtures.

ARE you, as an imaginative designer, often frustrated by the conventional louvered "boxes" that house the fluorescent lamp? Sometimes, after planning a beautiful room, original and distinctive, do you despair in your efforts to design a harmonious lighting effect?

Shown here is a completely new and dramatic development in fluorescent lighting—a designer's dream come true! The Variform uses soft, lovely, molded Plexiglas—circles, ovals, rectangles, squares—in a choice of sizes ranging up to eight feet in length.

We call this revolutionary luminaire the LPI Variform, its name derived from the fact that it supplies such a variety of forms for you to work with. Think of the possibilities for striking arrangements in perfect harmony with the dominant motif of the room! There is no limit to the original effects you can achieve. Truly, New Horizons invite you in this handsome and versatile new luminaire—the LPI Variform.





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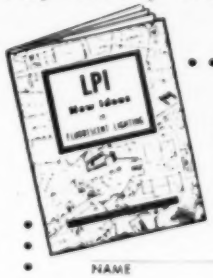
Variform shapes combine harmoniously with recessed troffers, incandescent down-lights and other standard equipment. Only standard straight fluorescent lamps are used.

Plexiglas absorbs less than 1% of luminous energy. Shatterproof, it will give many years of trouble-free service. Guaranteed not to sag, warp, lose shape or to discolor. Light in weight, easy to handle. Quickly cleaned with damp cloth, using mild detergent and water. Number of lamps used inside fixture is determined by degree of light output required.

mail coupon now for complete set of Variform drawings and specifications. You will also receive the latest LPI catalog, fully illustrated with photographs and drawings, "*New Ideas in Fluorescent Lighting.*"



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Reception lobby, corridors, and ten private offices at Thew Shovel Company, Lorain, Ohio, are lighted by "Wakefield Geometrics" luminous ceilings that include rigid-arch diffusers of PLEXIGLAS. The ceilings are manufactured by F. W. Wakefield Brass Company, Vermilion, Ohio.

New type of large-area lighting with **Formed Diffusers** of **PLEXIGLAS**

Here is a new development in the use of PLEXIGLAS acrylic plastic for luminous ceilings. Each of the four-foot-square diffusers in the installation shown above is a shallow *dome*, formed from white translucent PLEXIGLAS. The domed design gives structural rigidity to the panels, making the use of such large diffusers completely practical from the standpoints of safety, ease of handling, and permanence of shape.

Notice how the use of PLEXIGLAS results in uniform, efficient diffusion of light from completely concealed fluorescent lamps. Three lamps are mounted above each panel on separate controls for three levels of illumination, ranging from 50 to 90 footcandles. Diffusion is so complete that panels are illuminated evenly at each level of light intensity.

In addition to formability and efficient diffusion, PLEXIGLAS offers other advantages in lighting—strength, light weight, dimensional stability, and resistance to breakage and discoloration. For better lighting, investigate the use of PLEXIGLAS for luminous ceilings and large-area fixtures. We will be glad to send you illumination data on the installation shown above.

PLEXIGLAS is a trademark, Reg. U. S. Pat. Off. and other principal countries of the Western Hemisphere.

CANADIAN DISTRIBUTOR: *Crystal Glass & Plastics, Ltd., 130 Queen's Quay at Jarvis Street, Toronto, Ontario, Canada.*

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Representatives in principal foreign countries

(Continued from page 12A)

scheduled between conferences for further local interest.

2. **Les membres du chapitre de Quebec,** sur l'invitation de l'Aluminum Co. of Canada Ltd., se rendraient par autobus à Arvida et Shipshaw le 20 avril pour visite industrielle. L'Aluminum Co. ont invité le réunion à un lunch au Saguenay Inn.

3. **Capital Section** is another group which has found that extension meetings spread the gospel and at the same time stimulate local interest. Their latest such was in Richmond, Va., April 13, held jointly with the Electric League of Richmond.

4. **Oklahoma Chapter** in Tulsa invites members' wives to every meeting. They like it, technical subjects and all. At a recent meeting on measuring instruments, the distaff side operated the instruments and added interest to the subject, both technically and socially.

I.E.S. Extension Meeting Held in Sioux Falls, S. D.

An attendance of 73 indicates the interest in the extension meeting of the Twin City Section in Sioux Falls, S. D., March 20. Local Representative G. W. Frederick, General Electric Lamp Division and J. H. Gibbs, Tri State Electric Co. in Sioux Falls planned the program, which included:

"What the Illuminating Engineering Society Is and Does" — Midwestern Regional V P L. B. Paist, Northern States Power Co., Minneapolis.
"Quantity and Quality of Lighting" — L. E. Johnson, Northern States Power Co.
"New Developments in Light Sources" — John Williams, Lamp Division, General Electric Co.
"Economics of Lighting" — L. E. Johnson, Northern States Power Co.

The interest in this activity shown at the meeting points toward the formation of a Study Club in the near future.

Architectural Illumination — Topic Of North Carolina Conference

A broad scope of the various aspects of light, vision and lighting application was covered in the Conference on Architectural Illumination, held February 27-28 at North Carolina State College, Raleigh, N. C. The two-day meeting was sponsored by the College's School of Design of the Department of Architecture and Extension Division. The total attendance of 85 consisted of local architects, architecture students, consulting engineers, utility lighting engineers and wholesalers' salesmen from the Piedmont region.

The first session, afternoon of the 27th, was opened by Dean Henry L.

(Continued on page 18A)

LIGHTING CALENDAR

Society Events

May 18-19, 1953 — Southern Regional Conference, Sedgefield Inn., Greensboro, N. C.

May 25-26, 1953 — Great Lakes Regional Conference, Syracuse Hotel, Syracuse, N. Y.

September 14-17, 1953 — Illuminating Engineering Society, National Technical Conference, Commodore Hotel, New York, N. Y.

Industry Events

May 18-22, 1953 — National Materials Handling Exposition, Convention Hall, Philadelphia, Pa.

May 19-22, 1953 — Electrical Manufacturers Representatives Association of Michigan, Exhibition Building, Michigan State Fair Grounds Detroit, Mich.

May 24-28, 1953 — National Association of Electrical Distributors, 45th Annual Convention, Conrad Hilton Hotel, Chicago, Ill.

June 1-4, 1953 — Edison Electric Institute, 21st Annual Convention, Atlantic City, N. J.

June 8-10, 1953 — National Association of Electrical Distributors, Pacific Zone, Huntington Hotel, Pasadena, Calif.

June 9-12, 1953 — Store Modernization Institute, Fourth Annual Modernization Show, Madison Square Garden, New York, N. Y.

June 15-19, 1953 — American Institute of Electrical Engineers, Summer General Meeting, Atlantic City, N. J.

June 22-26, 1953 — Annual Convention of the American Society for Engineering Education, University of Florida, Gainesville, Fla.

June 28 - July 2, 1953 — American Society of Mechanical Engineers, Semi-Annual Meeting, Statler Hotel, Los Angeles, Calif.

July 5-10, 1953 — New York Lamp Show, Hotel New Yorker, New York, N. Y.

August 5-8, 1953 — International Association of Electrical Leagues, 18th Conference, Fairmont Hotel, San Francisco, Calif.

September 1-4, 1953 — American Institute of Electrical Engineers, Pacific General Meeting, Hotel Vancouver, Vancouver, B. C., Canada.

September 21-26, 1953 — International Association of Electrical Inspectors, 25th Jubilee Meeting, Edgewater Beach Hotel, Chicago, Ill.

September 23-25, 1953 — Canadian Electrical Manufacturers Association, Annual Meeting, General Brock Hotel, Niagara Falls, Ont.

October 5-9, 1953 — Society of Motion Picture and Television Engineers, Semi-Annual Convention, Hotel Statler, New York, N. Y.

October 19-21, 1953 — American Standards Association, 35th Annual Meeting, Waldorf-Astoria Hotel, New York, N. Y.

October 19-23, 1953 — National Safety Council, 41st National Safety Congress & Exposition, Chicago, Ill.

November 2-6, 1953 — American Institute of Electrical Engineers, Fall General Meeting, Muehlebach Hotel, Kansas City, Mo.

November 9-12, 1953 — National Electrical Manufacturers Association, Haddon Hall Hotel, Atlantic City, N. J.

November 16-20, 1953 — National Electrical Contractors Association, Miami Beach, Fla.

November 29 - December 4, 1953 — The American Society of Mechanical Engineers, Annual Meeting, Statler Hotel, New York, N. Y.

January 18-22, 1954 — American Institute of Electrical Engineers, Winter General Meeting, New York, N. Y.

March 8-11, 1954 — National Electrical Manufacturers Association, Edgewater Beach Hotel, Chicago, Ill.

LIGHT SOURCES and Sorcery, an "on-the-road" show by the Pennsylvania Power and Light Company, outlines to civic and business groups and high schools the production of light from man-made sources. During the last year and a half, the company's lighting consultants have given this demonstration to over 100,000 persons.

(Continued from page 17A)

Kamphoefner, Department of Architecture, who outlined the scope and purpose of the meeting. About 75 slides, with comments by all participants, were then shown to indicate the general nature of the conference. The program continued with the following speakers:

"Color, Light and Living"—by R. P. Bell, Asst. General Paint Manager, Pittsburgh Plate Glass Co.

"Illumination and Visual Perception"—C. R. Kelley, Associate Director of Occupational Vision Research at the College and Asst. Professor of Psychology.

The second session, in the evening, gave three viewpoints of the art of lighting with these topics and speakers:

"The Meaning of Light in Architectural Design"—Richard Kelley, lighting designer and engineer, New York City.

"Lighting Design Objectives"—C. M. Cutler, General Electric Co., Cleveland.

"The Relation of Light to Form"—Louis I. Kahn, Philadelphia architect and Chief Critic in Architectural Design at Yale University.

The third session was a panel symposium to resolve new problems of lighting in architecture. Speakers from all four sessions, plus local architects and engineers, formed the panel, and the audience participated in discussion.

The final session, on the afternoon of the second day, was concerned with sources of information and methods of procedure, covering:

"General Bibliography of Natural and Artificial Light Study, Research and Writing"—Berlon C. Cooper, Eastern Editor, *Electrical Construction and Maintenance*.

"Methods"—C. M. Cutler, General Electric Co.

Copies of the Bibliography by Mr. Cooper were distributed to all in attendance.

Dean Kamphoefner of the Department of Architecture presided at all sessions and served as moderator for all panel and audience discussion periods.

Annual Spring Conference Sponsored by Iowa Section

The annual Spring Conference of the Iowa Section was held March 27, at the Blackhawk Hotel in Davenport, Iowa. The meeting was opened by James H. Hull, Section Chairman, and delegates were welcomed by C. P. Conrad, President of the Iowa Illinois Gas and Electric Co. The program, arranged by H. A. Weibel, General Electric Co., continued with:

"Types of Fluorescent Lamps," by Newell Willard, General Electric Co., Davenport, Iowa.

"Plastics as Applied to Illumination," by H. A. Williams, Rohm and Haas Co., Philadelphia, Pa.

"Economics of Group Replacements for Lighting Systems," by Carl F. Jensen, Westinghouse Electric Corp., Chicago, Ill.

"Recent Items of Lighting Progress," by T. C. Sargent, Sylvania Electric Products, Inc., Salem, Mass.

A hospitality hour, with Iowa-Illinois Gas and Electric Co. as host, followed.

Airport Lighting Panel Discussion Featured at Kansas City Meeting

A panel discussion on airport lighting by members of the I.E.S. Committee on Aviation Lighting was a feature of the Congress of Civil Aviation Conferences held in Kansas City, Mo., March 22-26. Lighting problems were discussed and questions from airport managers and operators were answered by the panel. The meeting was attended by members of fifteen of the leading national aviation organizations, marking the golden anniversary of flight.

C. R. Seybold, Civil Aeronautics Administration, Chicago, discussed airport lighting units in use today, saying they are from five to ten years old, and that over 30,000 of the semi-flush runway marker lights—"the trouble-maker of all time"—are still in service. Mr. Seybold stated that the use of elevated marker light units and non-metallic armored cable has made the later types of airport lighting systems more vulnerable to lightning damage with four out of five lightning strokes originating on the landing area itself rather than on the incoming power line.

L. B. Lattin, Hevi Duty Electric Co., spoke on the need for correct setting of input voltages for static regulators and the problems imposed by not replacing burned-out runway or taxiway lamps promptly.

Guidance signs to replace existing taxi lights were suggested by John S. Haney, Crouse-Hinds Co., predicting that they will widely replace the present entrance-exit lights. He also predicted that transmissometers will be used more and more for the operation of runway lights and approach lights for instrument landings, and that they are already being considered for automatically regulating the brightness control of lights.

According to R. E. Madigan, Line Material Co., a great deal of engineering time spent on the design of airport lighting units is wasted by improper and faulty installation and application. He urged that installation specifications be improved and that systems be better maintained after installation.

J. A. McDougall, Revere Electric Mfg. Co., discussed high elevation mounting of apron and ramp floodlights, using inner visors, to reduce objectionable glare. He also spoke on the use of hinged mounting poles for floodlights to cut down the labor in servicing them.

The fluorescent ramp and apron lighting installation at the General Lawrence Logan Airport, Boston (see I.E., November 1952, p. 585) was described by D. T. Carter, General Electric Co., giving the advantages claimed by this system.

The use of the new type high intensity flush runway lights on military airfields was discussed by W. R. Davies, Westinghouse Electric Corp., who also reminded civilian airport managers and operators of the troubles with flush type lights from the maintenance angle.

At the technical conference held by the Committee on Aviation Lighting, J. P. Warner, consulting engineer, spoke on the lighting of the Greater Pittsburgh Airport (see I.E., January 1953, p. 3), which he had planned. He illustrated his talk with color slides showing the lighting of the various parts of the new

(Continued on page 22A)

NEW TYPE lighted sign for airport taxiways is inspected by the I.E.S. Aviation Lighting Committee, attending a technical conference in Kansas City. This type sign will be installed at the New Greater Pittsburgh Airport.

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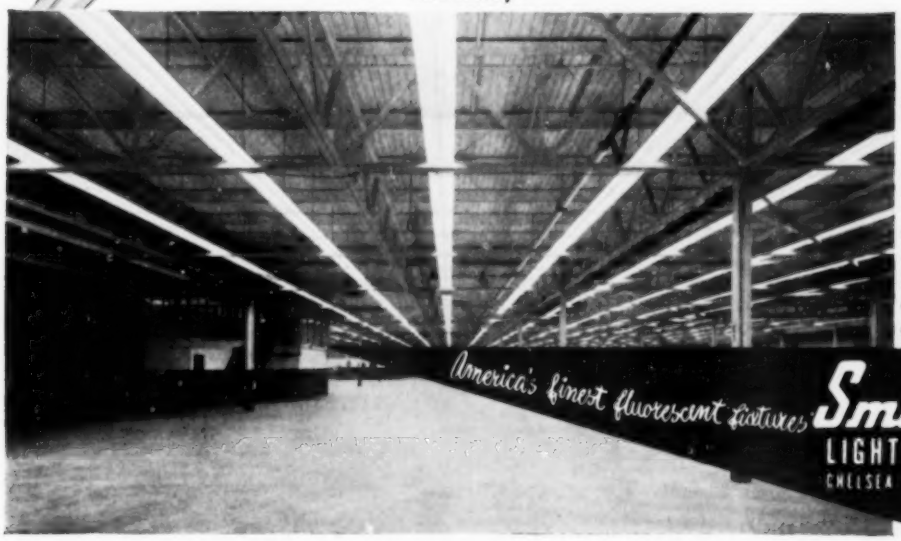

Continuous row installation in one of the nation's newest and most modern plants . . . over 5000 Smithcraft A.L.S. 8' Industrial Slimline units lighting 397,000 sq. ft. of floor space. Notice the continuous lines of light with no interrupting dark areas between fixtures and how uplighting lights the ceiling reducing contrast.

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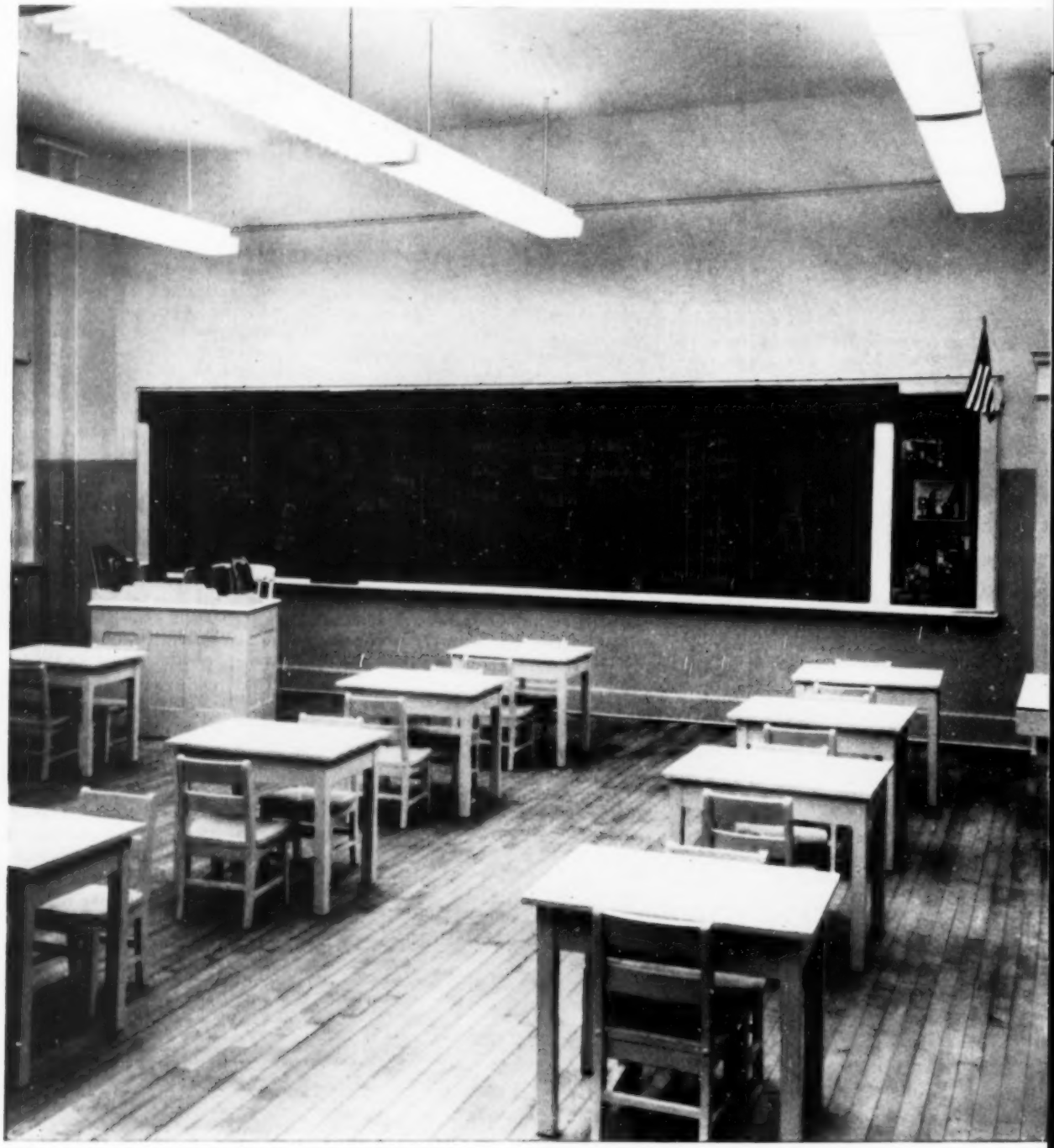
*Merit award winner at International Lighting Exposition



. . "It's easy to maintain this high level of illumination with Westinghouse CC Luminaires"

"We needed up-to-date lighting, and hoped to keep our operating and maintenance costs reasonable. That's one important reason we selected the Westinghouse CC design," reports Superintendent Jones, North Haledon, New Jersey.

By suspending the CC luminaire, advantage was taken of both ceiling and luminaire to provide improved desk-top illumination at lower cost. Combined with a completely redecorated classroom, the CC provides comfortable illumination. Both in brightness ratios and illumination levels, the North Haledon classroom exceeds every requirement of the American Standards Practice for School Lighting—sound basis for the Merit Award.

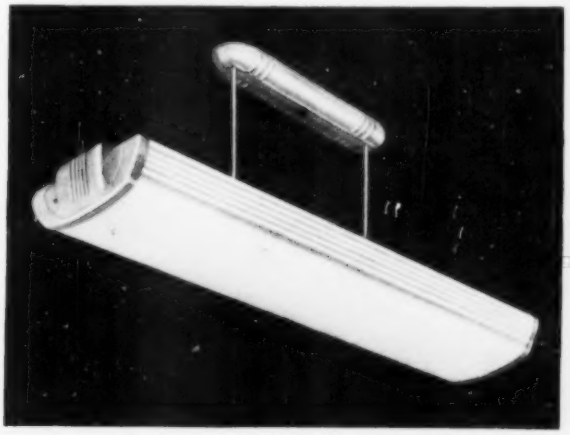
A much improved situation now exists: from 4 footcandles to over 48 *maintained footcandles.* As Superintendent Jones says, "Both students and teachers are enthusiastic about the new lighting. It makes a big difference."

Equally important, maintaining high illumination levels with the Westinghouse CC is both practical and easy. Plastic sides and louver shielding cut cleaning time to a minimum. There are no dust and dirt-collecting surfaces. Re-lamping is easily done from the top.

Westinghouse has a complete line of fluorescent and incandescent luminaires which meet the variety of classroom lighting requirements. Why not look them over? Get B-4556, *The ABC Plan for School Lighting,* Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pennsylvania. J-04341

And to meet other requirements . . .

Low FIRST cost Concentric Ring incandescent luminaires meet quality lighting requirements on limited funds. Metal rings shield silvered bowl lamps, eliminating glare and shadows.



Deluxe styling and comfortable illumination with the Westinghouse CD luminaire with plastic shielding. The entire ceiling becomes part of the lighting system; all lamps are completely shielded.

YOU CAN BE SURE... IF IT'S
Westinghouse

(Continued from page 18A)

administration building, ramp and service areas.

Maurice Laufer, Grimes Mfg. Co., described a new navigation light with a rotating beam, providing over 4,000 beam candlepower, for installation on air carrier and other larger types of aircraft. The light contains a 100w sealed beam lamp shining vertically on a double reflector which is rotated at 40 rpm by a small electric motor.

A paper by R. K. Davis, Wright Air Development Center, was presented by Paul Greenlee, Grimes Mfg. Co. The paper stated that lighting for aircraft should be considered when the aircraft is on the drawing board. Mr. Greenlee also described a new 500 watt flush runway marker light under development.

The development of another new unit — to provide the "Ideal Beam Pattern for Runway Lights" — was discussed by J. J. C. Pearson, Civil Aeronautics Administration, and R. W. Madigan, Line Material Co.

N. Y. Residence Lighting Forum Holds Joint Meeting with A.I.A.

Mutual problems facing the residential architect and the lighting designer as a result of current architectural trends were discussed at the joint meeting of the New York Residence Lighting Forum and the New York Chapter of the American Institute of Architects, April 23.

Richard Kelly, lighting designer and engineer, was moderator of a panel of architects and lighting engineers, which included Louis Kahn, Yale University School of Architecture; Henry Hebbeln, architect; Thomas Smith Kelly, lighting engineer and consultant; and Harry McNary, lighting engineer of Fischbach and Moore.

Under the general title of "New Problems of Light Created by Contemporary Architecture," the discussion covered the integration of the mechanics and functions of lighting with design structure, designing for continuity of light for both day and night orientation, flexibility of lighting systems required by open planning and multi-use of space, the problems created by the use of large areas of glass, and the use of outdoor space as affected by lighting.

Lighting Design Award In Detroit Contest

A competition for a lighting design for the new Convention Hall to be built in Detroit's Civic Center was sponsored by the Michigan Section of the American Institute of Architects. David Hamilton, Detroit designer, was the winner of the $1,000 prize donated by the Kirlin Co. The prize was awarded March 15 at the annual banquet following the three-day meeting of the Institute. Judges in the contest were illuminating engineers J. W. Snyder and George Wagshall, and architects Jean Hebrard, W. D. Riddle, and F. G. Stickel.

AT A MEETING March 23 of the Oklahoma Section, I.E.S., in Tulsa, aviation lighting was discussed by David Miller (left), General Electric Co., whose presentation covered present practice in airport and aircraft lighting; the superiority of deep red illumination for instrument lighting; the effect of atmospheric absorption and flashing on effectiveness of signal beams; and a Navy BuAer film on the evaluation of high intensity lights and FIDO for helping land aircraft under extremely adverse atmospheric conditions. Maurice Laufer (center) and Paul Greenlee (right), Grimes Mfg. Co., participated in answering questions from the fifty members and guests present.

Cleveland Section Sponsors Course in Architecture

The Committee on Allied Arts and the Education Committee of the Cleveland Section are currently sponsoring a Short Course in Architecture, including discussions of pre-modern and modern styles and construction; the changing forms of commercial, industrial and residential buildings; painting and sculpture as adjuncts to architecture. Lecturers include Dean Francis R. Bacon, Western Reserve University School of Architecture; Professor Edmund Chapman, Western Reserve University Department of Art; Ernst Payer, Architect; and Wilbur Riddle, Architect.

The five sessions, weekly from April 22, will conclude May 20 with a tour of architecturally significant buildings in Cleveland. Lindsey Davis and Karl Staley, chairmen of the two committees, planned the course. Tuition was five dollars.

Green Bay Study Club Has Active Year

Under the guidance of the extension activities committee of the Milwaukee Section, the Green Bay, Wisconsin Study Club has been holding monthly meetings with an average attendance of 15. Officers of the club are Chairman, Edward Shepard; Vice-Chairman, R. L. Salzgeber; Secretary-Treasurer, Howard R. Johnson. Topics discussed at meetings have been:

Organization and Benefits of I.E.S. — B. R. Bunn, of the Milwaukee Section.
Good Lighting Practice.
Architects' Viewpoint on Lighting — Gordon Feldhousen and John Somerville, Green Bay Architects.
Quality in Lighting Application — Adrian Goldschalx, Appleton Consulting Engineer.

College Engineering Enrollments Climb

According to Engineering Manpower Commission of Engineers Joint Council, the 51,631 new students entering in the Fall of 1952 represent the third largest class ever to enter engineering schools. Exceeded only in 1946 and 1947, the number of new engineering students account for almost 16 per cent of all male students entering college for the first time in 1952. Assuming normal progression of the current entering class of enginering students, the resulting number of graduates in 1956 will be in the neighborhood of 30,000. So states the January 1953 Circular #346, titled, Engineering Enrollments and Degrees, 1952, which was compiled under the auspices of the Federal Security Agency—Office of Edu-

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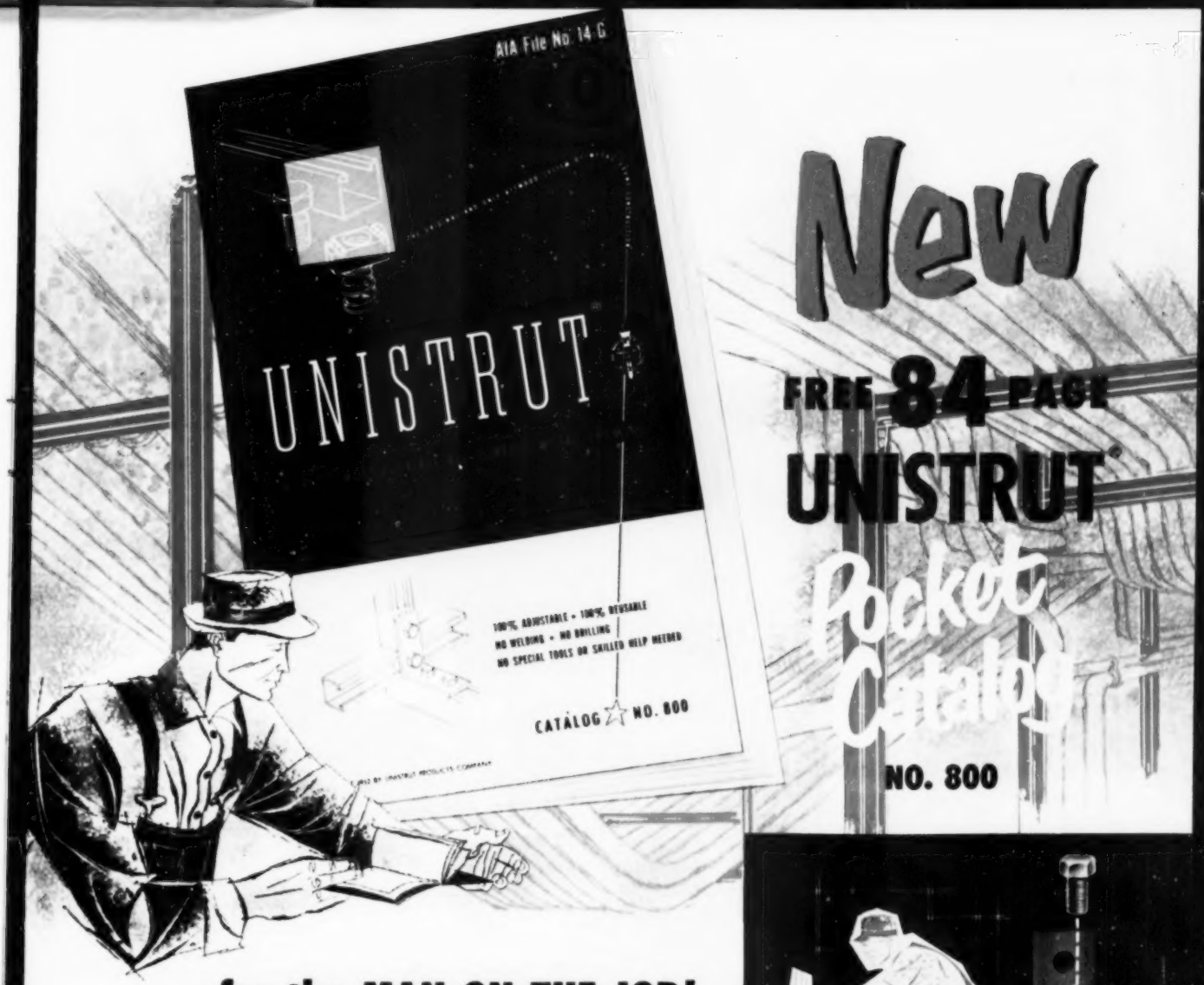
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(Continued from page 22A)

cation by Robert C. Story, Head, Statistical Services Unit, Research and Statistical Standards Section and Henry H. Armsby, Chief for Engineering Education, Division of Higher Education.

This survey which reports data supplied by 149 institutions offering curricula accredited by E.C.P.D., and by 44 institutions in which no curriculum is so accredited, points out that the 20,469 engineering graduate students enrolled in the Fall of 1952 represent an increase of 4.2 per cent over the preceding year.

While the graduation estimates for the next four years reported upon show no material deviation from those now in EMC files, it is interesting to note the increased tendency on the part of students entering college toward engineering.

MEMBERS of the I.E.S. Committee on Street and Highway Lighting met at the Ansley Hotel in Atlanta, Ga., March 26-27. Pictured here are: front row, R. M. Zabel, J. B. Browder, F. D. Wyatt, C. H. Rex, G. K. Glass, C. A. B. Halvorson; second row, H. F. Ilgner, J. H. Murrah, S. R. Williams, R. P. Brotzman, L. J. Schrenk; third row, F. J. Schmitt, G. W. Izant, Ray Palmer, R. S. Bucher, A. B. Winters, C. L. Crouch; fourth row, D. W. Rowten, J. F. McGough, R. G. Slauer, J. H. Fahey, L. F. Heckmann, H. E. Mason; back row, G. E. Korten, R. M. Swetland, J. L. Eberly, D. A. Toenjes, A. R. Jaeger, J. W. Lewis, H. W. Osborne.

Chicago Programs Continue in High Gear

Continuing its series of specialized lighting clinics, the Chicago Section, I.E.S., and the Chicago Lighting Institute offered May 8 a full-day conference on Industrial Lighting. Co-sponsors with I.E.S. and C.L.I. were the Chicago Association of Commerce and Industry and the Electrical Maintenance Engineers of Chicago. The all-day program was as follows:

Morning Session—Chairman: Chester Thorsen, Day-Brite Lighting, Inc., Chicago, Ill.

"Good Factory Lighting Is Common Sense"—E. J. Fitzgerald, E. I. du Pont de Nemours, East Chicago, Ind.
"Basic Facts About Industrial Lighting"—W. D. Richards, Lighting Engineer, Chicago Lighting Institute.
"Lamps for Industry"—Samuel H. Eaton, Sylvania Electric Products, Inc., Chicago, Ill.
"Preventing Thrombosis in Current Carrying Arteries"—John H. Pierce, Pierce Electric Co., Chicago, Ill.

Afternoon Session—Chairman: Hoyt P. Steele, Benjamin Electric Mfg. Co., Des Plaines, Ill.

"Lighting the Industrial Plant"—Panel Discussion on General Area Lighting, High-Bay Area Lighting, Inspection Lighting, Special Applications.
Moderator: Glenn G. Boyd, Public Service Co. of Northern Illinois. Panel: B. S. Benson, Benjamin Electric Mfg. Co.; E. E. Elliott, Hawkins Electric Co.; R. F. Diefenthaler, General Electric Co.; Irwin Meyer, Appleton Electric Co.; John McLaughlin, Kelso-Burnett Electric Co.
"Trends in Industrial Lighting"—Hoyt P. Steele, Benjamin Electric Mfg. Co., Des Plaines, Ill.

The annual course in Lighting Fundamentals sponsored by the Institute continues its Spring Quarter with lecture and laboratory sessions by William Richards and Raymond Wozniak. Wiring design—I, with Frank McShane as instructor, is also being presented.

General Course in Illumination Presented by Arizona Chapter

A three-day general course in illumination aimed at the executive, student, salesman, consulting engineer, architect and contractor, was presented by the Arizona Chapter of I.E.S. April 13, 14, and 15. Under the direction of J. D. Whitnell, Chapter Chairman, the classes were held in the auditorium of the Arizona Public Service Co., in Phoenix. Topics covered in the three 3-hour sessions were:

Light, Vision, Mechanism of the Eye; Light Sources.
Illumination Terminology; Quantity and Quality of Light; Principles and Systems of Light Control; Interior Light Design; Office Lighting; School Lighting.
Store Lighting; Floodlighting; Industrial Lighting; Residential Lighting; Question and Answer Period.

Instructors for the various subjects discussed were:

E. F. Larson, Westinghouse Electric Corp., Los Angeles, Calif.
C. M. Cutler, Lamp Division, General Electric Co., Cleveland, Ohio.
H. Dean Cage, Doctor of Optometry, Scottsdale, Ariz.
S. L. Burnham, Lamp Division, General Electric Co., Phoenix, Ariz.
T. L. Buckley, Arizona Public Service Co., Phoenix, Ariz.
J. D. Whitnell, Arizona Public Service Co., Phoenix, Ariz.
E. A. Eaton, Arizona Public Service Co., Phoenix, Ariz.

Registration for I.E.S. members was $1.50, for nonmembers, $3.00. Enrollment was limited to 125.

ABOUT PEOPLE

William F. Little, past president of I.E.S., has been elected President of Electrical Testing Laboratories Inc. **Leonard J. Lewinson** has been named Executive Vice President and **Norman D. Macdonald,** Vice President. **F. Malcolm Farmer,** retiring President of the company, continues on the Board of Directors, of which he has been elected Honorary Chairman.

George L. Wilcox has been elected vice-president and a director of the Westinghouse Electric International Co., by the firm's Board of Directors. Formerly general sales manager for the company, Mr. Wilcox has been with Westinghouse since 1942 when he joined the parent company as a design engineer.

Fergus M. Sloan, electrical engineer with more than 21 years' service with Westinghouse Electric Corp., has been named manager of the company's Lamp Division. Until his recent appointment, Mr. Sloan was operations manager of the Television-Radio Division at Metuchen, N. J. and Sunbury, Pa. He took over active management at the Bloomfield Headquarters on May 1.

(Continued on page 26A)

ELECTRICAL contractors who were among the winners of sixteen cash prizes awarded in the 1952 Lighting Campaign, sponsored by the Philadelphia Electrical Association's Lighting Equipment Manufacturers and the Philadelphia Electric Co. Awards were made at the March meeting of the Philadelphia Section, I.E.S. Pictured here are, seated, John DiMedio, Edwin H. Henrie, Richard Manopello, Edward Barber, Howard McKim, Jack Adler, Andy Camp; standing, William Murphy, Harry G. Hey, Charles A. Holm, James H. Lomax, Robert Keough, and Charles I. Johnson.

(Continued from page 25A)

The purchase by the Benjamin Electric Mfg. Co. of certain assets of the Leader Electric Co., Chicago., was announced by **Hoyt P. Steele,** Executive Vice-President of Benjamin Electric Mfg. Co., Des Plaines, Ill. The Leader Line will be manufactured and sold by the Leader Division of Benjamin.

At the 22nd Annual Meeting of the Inter-Society Color Council held March 18 at the Hotel Statler, New York City, **Dorothy Nickerson,** Production and Marketing Administration, U.S.D.A., was presented with a resolution of appreciation for her service and her guidance as Secretary of the Council. Miss Nickerson was Secretary of the I.S.C.C. for many years before resigning from that position last year. In addition to the resolution, Miss Nickerson received a mahogany desk with a silver plaque indicating its origin.

Five major appointments and the establishment of a new operating division have been announced by Corning Glass Works. **John L. Hanigan, Frederick H. Knight** and **Henry H. Sayles** were elected Vice President, Secretary and Assistant Secretary respectively. **Thomas Waaland** was appointed Director of Industrial Relations and **John F. G. Hicks** was made General Manager of the newly formed International Division. The new division will consolidate under one head all foreign activities of the company.

Holophane Co., Inc., announces the following changes in territorial coverage: **Daniel R. Donnelly,** New York District Manager is servicing the metropolitan area in cooperation with **Edward L. Gluck** and **Willard L. Warren; Robert W. Stanley** is District Manager in Connecticut and western Massachusetts, with headquarters in Hartford; and **Adriaan Van Oss** is District Manager in Michigan with headquarters in Detroit.

J. H. Kempner has been appointed sales manager of Reliable Plastic Corp., with his headquarters at 333 North Michigan Ave., Chicago, Ill. Mr. Kempner was formerly with Southern Plastics Co., Columbia, S. C.

Curtis Lighting, Inc., has announced an expansion program involving redistricting of territories. **J. V. Bradley,** former Boston territory representative, has been appointed Regional Manager for the East Coast with headquarters at 545 Fifth Ave., New York City. **W. J. Dorrans,** Minneapolis representative, will head the Northwest Central Region, operating out of headquarters office in Chicago. The Southwest Central region will be under the supervision of Regional Manager **C. F. Peterson,** with headquarters in Dallas.

General Electric's Construction Materials Division has announced the consolidation of the Wiring Device Department at Bridgeport, Conn., and the Monowatt Department at Providence, R. I., and has appointed **A. F. Warren** and **Arville W. Gilmore** as general manager and assistant general manager for the consolidated department.

Robert Ford, formerly with Southern California Edison Co., and **Mel Fenton,** formerly with Graybar Electric Co., are now with Smoot-Holman Co., Sacramento, Calif.

F. M. Pyle has been appointed Director of Sales and Product Development of Metalcraft Products Co., Inc., Philadelphia, Pa.

OBITUARY

Joseph M. Supple, vice-president of Eaco, Inc., New Orleans, died April 4 after a coronary thrombosis attack. Mr. Supple had been Chairman of the New Orleans Section for the 1946-1947 term when the city was host to the I.E.S. National Technical Conference in 1947. He had also served the Society on the Committee on Project Planning and as Chapter Representative of the Committee on Lighting Education.

NEW MEMBERS

At the meeting of the I.E.S. Council, held in Dallas, Texas, on April 13, the following were elected to membership:

ALABAMA CHAPTER

Members:
Broughton, W. J., Jr., Appleton Electric Co., Birmingham, Ala.
Cale, L. T., Alabama Power Company, Birmingham, Ala.
deFuniak, A. F., II, Alabama Power Co., Birmingham, Ala.
Johnson, S. A., Alabama Power Company, Birmingham, Ala.
Perreault, M. A., Graybar Electric Co., Birmingham, Ala.
Associate Member:
Gettys, John, Jr., Matthews Electric Supply Co., Birmingham, Ala.

CAPITAL SECTION

Member:
Bigelson, Arthur, General Engineering Associates, Washington, D. C.
Associate Member:
Downing, Jack, Westinghouse Electric Corp., Richmond, Va.

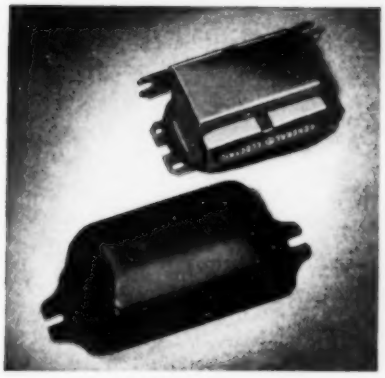
CAROLINAS SECTION

Members:
Campbell, R. S., 3 W. Plaza, Greenville, S. C.
Owens, B. B., Anderson Electric & Supply Co., Charlotte, N. C.
Associate Members:
Hallman, R. E., Westinghouse Electric Supply Co., Greenville, S. C.
Henley, R. L., Dyer-Clark, Inc., Spartanburg, S. C.
Martin, T. E., General Electric Co., Raleigh, N. C.
Ripley, N. S., General Electric Supply Co., Charlotte, N. C.

CENTRAL NEW YORK SECTION

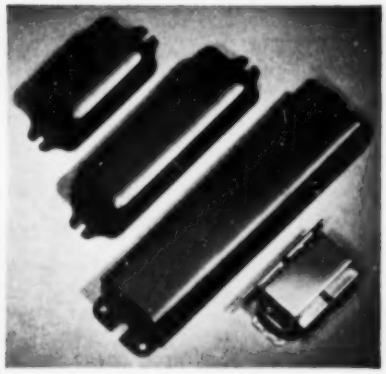
Associate Members:
Lindstrom, Einar, Lindstrom Electric Co., Syracuse, N. Y.
Ryan, J. L., City Electric Co., Inc., Syracuse, N. Y.

(Continued on page 30A)



SMALLER . . .

LIGHTER . . .



REPLACES 3 . . .

How to get smaller, quieter fixtures with the new G-E Clamped Core Ballast

You can reduce the weight, size and noise level of your small fluorescent fixtures by equipping them with General Electric's new clamped core ballast.

You can streamline your ballast stocks and simplify your ordering because the new clamped core ballast is designed to replace up to nine previous G-E ratings (three case sizes).

You can solve design and production problems with the compact clamped core ballast because its universal mounting clamp allows you to install it in any position.

And for partially open fixtures which must meet "suitability of enclosure" requirements for U.L. listing, you can order G.E.'s clamped core ballast with a metal lock-on cover.

The lock-on cover is a unique feature of G.E.'s clamped core design. It lets you incorporate savings in size, weight and cost into nearly every type of small fluorescent fixture except those which are "open" or "wide open"—that is, where the ballast is directly exposed either to air or to the fixture mounting surface.

In sign applications, the G-E clamped core ballast with lock-on cover is considered by Underwriters' Laboratories to be an enclosed unit, and can be used as encased and compounded units have been used previously. Most other small fluorescent fixtures which have reasonably close fitting joints and seams and no openings except those needed for assembling and mounting can use the clamped core ballast with no extra cover whatever.

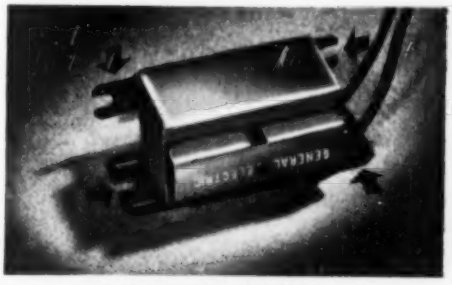
1878 75 1953 YEARS OF ELECTRICAL PROGRESS

For detailed information on how you can use the new G-E clamped core ballast to make your fixtures smaller, lighter, and quieter, contact your nearest G-E Apparatus Sales Office or authorized G-E Distributor. Or write for Bulletin GED-1868; address Section 412-104, General Electric Company, Schenectady 5, New York.

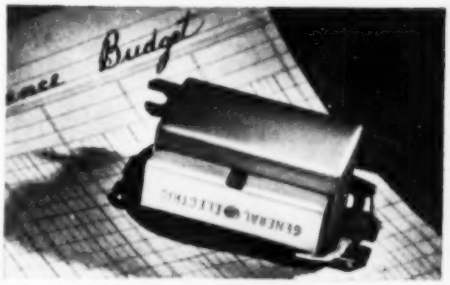
You can put your confidence in—

GENERAL ELECTRIC

QUIETER . . .



EASIER MOUNTING . . .



COSTS LESS

announcing the most

Revolutionary fixture design in the last decade

Patent Applied for

Now, for the first time, FIVE outstanding construction features, each a new concept of fixture engineering, that will save at least one fourth of installation and maintenance costs. These important innovations, *found only in the Gibson HOLO-77*, are available at no increase in cost over conventional quality fixtures.

UNI-RACE*, a sectional beaded channel that provides automatically exact fixture spacing with calculated clearance between units — positive alignment — a continuous open wireway.

TERMINAL BLOCK CONNECTOR can be wired-in using only a screw driver in as little or 32 seconds. No lead, rubber tape or wire nuts required with 90% saving of wiring in time.

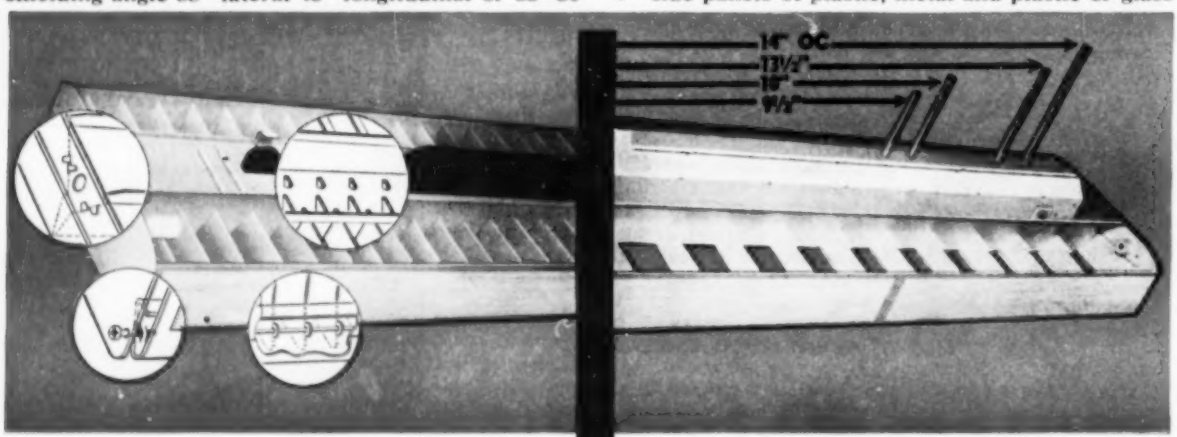
INTEGRATED CONSTRUCTION with each part locked to each adjoining part forming an inseparable unit of greatest possible strength and rigidity.

"V" TYPE GIRDER, $4\frac{3}{8}$" deep, capable of supporting more than 40 pounds at center without perceptible deflection in eight feet, provides the heart of this rugged unit.

DIVERSIFIED DUAL STEM MOUNTING providing adaptability to practically all dual stem sets without modification through positioning of multiple knockouts in the Uni-Race.

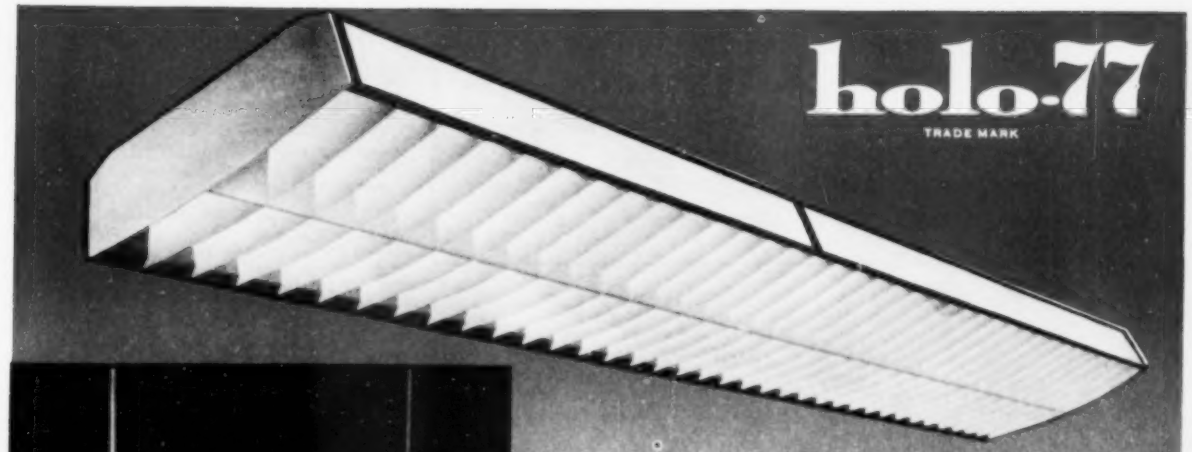
*Trade Mark

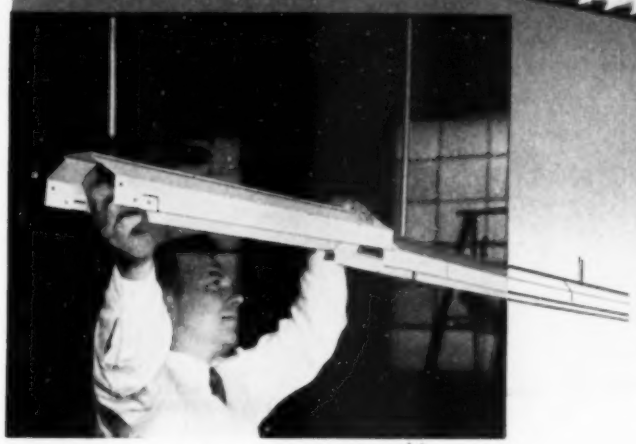
Standard fixture wired in rapid start or slimline • 40 watt, 62 watt, 75 watt • two and four lamp shielding angle 35° lateral 45° longitudinal or 35°-30° • side panels of plastic, metal and plastic or glass



INTEGRATED CONSTRUCTION

DIVERSIFIED DUAL STEM MOUNTING





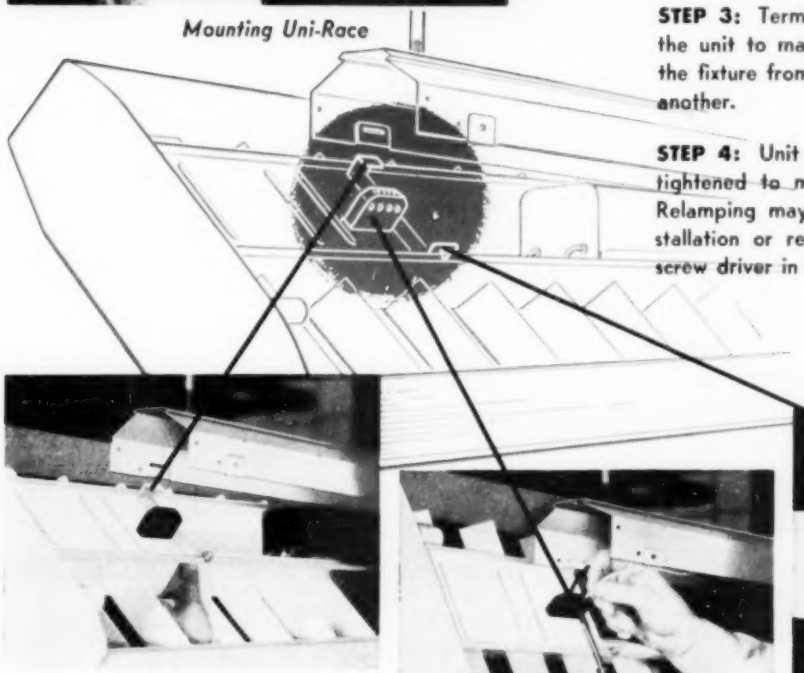
Mounting Uni-Race

STEP 1: Mount the Uni-Race, a rigid, readily accessible open wireway which can be infinite in length. It is adaptable to any type of mounting and is punched for automatic spacing in continuous runs to a tolerance of less than .040.

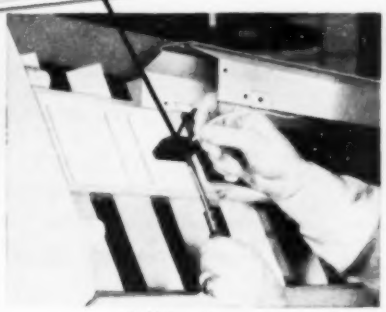
STEP 2: Hook the fixture in slots on the Uni-Race with as much ease as hanging an ordinary louver assembly. Slots on Uni-Race assure perfect alignment and spacing.

STEP 3: Terminal block connectors are provided on the unit to make a positive, solderless connection to the fixture from the Uni-Race and from one fixture to another.

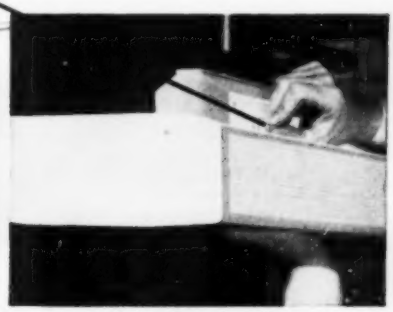
STEP 4: Unit is snapped closed and take-up screw tightened to make a rigid, vibrationless connection. Relamping may be accomplished in position and installation or replacement can be made with only a screw driver in less than 60 seconds.



Hanging Fixture



Wiring-in



Snapping closed

GIBSON *Manufacturing Co.* **1919 Piedmont Circle, N.E., Atlanta, Georgia**

I.E.S. National Technical Conferences

September 14-17, 1953 — Hotel Commodore, New York
September 12-16, 1954 — Chalfonte-Haddon Hall, Atlantic City
September 12-16, 1955 — Statler Hotel, Cleveland
September 16-21, 1956 — Statler Hotel, Boston.

(Continued from page 29A)

CHICAGO SECTION

Member:
Tuma, Charles, Jefferson Electric Co., Bellwood, Ill.

Associate Members:
Foulkes, J. F., Commonwealth Edison Co., Chicago, Ill.
Hayes, Cornelia, 400 Deming Place, Chicago, Ill.

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Jangarathis, J. C., University of Illinois, Urbana, Ill.
Josepher, Robert, University of Illinois, Urbana, Ill.
Priestap, K. G., University of Illinois, Urbana, Ill.

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Freeman, W. R., Sola Electric Co., Cleveland, Ohio.
Hart, A. L., General Electric Co., Cleveland, Ohio.
Hoffman, Donald, F. W. Wakefield Brass Co., Vermilion, Ohio.
Leyerle, A. R., Vitreous Steel Products Co., Cleveland, Ohio.

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EASTERN PENNSYLVANIA SECTION

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Fierman, G. S., Anthracite Electric Supply Co., Wilkes Barre, Pa.
Gilmer, J. W., Pennsylvania Power & Light Co., Sunbury, Pa.
Lehmber, R. W., Tremont Electric Co., Tremont, Pa.
Mistovich, Joseph, Westinghouse Electric Supply Co., Reading, Pa.
Reilly, E. T., General Electric Co., Newark, N. J.
Schmehl, R. C., Westinghouse Electric Corp., Reading, Pa.
Schreiner, C. D., Westinghouse Electric Corp., Allentown, Pa.
Stoyer, W. L., Westinghouse Electric Supply Co., Reading, Pa.

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Geffken, J. H., Geffken-Austin & Associates, Atlanta, Ga.

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Johnson, Guy, Noland Company, Atlanta, Ga.
Jordan, G. W., Jr., Georgia Power Co., Atlanta, Ga.

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Hernandez, A. G., Comision Federal de Electricidad, Mexico 5, D. F.
Rodriquez, Heron, Jr., Ingenieria Electrica y Iluminacion, Mexico 1, D. F.
Tapia, P., Comision Federal de Electricidad, Mexico 5, D. F.

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McDonald, J. H., Smith Hinchman & Grylls, Detroit, Mich.
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Beers, M. W., Westinghouse Electric Corp., Detroit, Mich.
Bryden, E. C., Graybar Electric Co., Detroit, Mich.
Clark, L. G., The Gayney Co., Detroit, Mich.
Fukuda, Frank, Smith Hinchman & Grylls, Detroit, Mich.
Gayney, M. A., The Gayney Co., Detroit, Mich.
Loud, H. S., The Detroit Edison Co., Detroit, Mich.

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Chenault, R. D., Treadway Electric Co., Inc., Little Rock, Ark.
Dixon, E. F., Treadway Electric Co., Inc., Little Rock, Ark.
Efird, E. M., Treadway Electric Co., Inc., Little Rock, Ark.
Gill, G. A., Treadway Electric Co., Inc., Little Rock, Ark.
Hogan, R. H., Arkansas Power & Light Co., Little Rock, Ark.
Knapp, H. A., Westinghouse Electric Co., Little Rock, Ark.
Maddox, E. E., Arkansas Power & Light Co., Little Rock, Ark.
McNutt, C. C., Southwest Engineering Co., Little Rock, Ark.
Miller, J. D., P. O. Box 351, Brinkley, Ark.
Newby, R. W., Arkansas Power & Light Co., Little Rock, Ark.
Phillips, F. H., Treadway Electric Co., Little Rock, Ark.
Reifsteck, F. R., Westinghouse Electric Supply Co., Little Rock, Ark.
Wynne, J. T., Treadway Electric Co. Inc., Little Rock, Ark.
Young, C. B., Treadway Electric Co. Inc., Little Rock, Ark.

MILWAUKEE SECTION

Associate Members:
Jacobs, G. C., Everbrite Electric Signs Inc., Milwaukee, Wis.
Jonas, R. G., The Jonas Co. Inc., West Allis, Wis.
Mitchell, J. S., Moe Brothers Milwaukee Co., Milwaukee, Wis.

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MOTHER LODE CHAPTER

Associate Member:
Fenton, M. P., Smoot Holman Co., Sacramento, Calif.

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Wendling, E. G., General Electric Co., Lynn, Mass.

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Associate Members:
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Campbell, L. J., Duro Test Corp., N. Bergen, N. J.

Student Member:
Arner, R. S., Columbia University, New York, N. Y.

NORTHERN CALIFORNIA SECTION

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Fennell, P. H., Jr., Fischbach & Moore, Inc., San Francisco, Calif.

Associate Members:
Anderson, A. W., Franklin Design Service, Oakland, Calif.
Hofheinz, M. C., Westinghouse Electric Corp., San Francisco, Calif.
Holm, Henrik, 474 Bryant St., San Francisco, Calif.
Leeb, B. R., The Electric Corp. of San Francisco, San Francisco, Calif.
Lynch, L. E., Lynch Electric Co., San Francisco, Calif.

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Misrach, W. V., Richards Electric Supply Co., Cincinnati, Ohio.

Associate Members:
Cook, E. A., Union Light Heat & Power Co., Covington, Ky.
Coyle, Paul, General Electric Supply Co., Cincinnati, Ohio.
Rapier, R. L., Cincinnati Gas & Electric Co., Co., Cincinnati, Ohio.
Rogers, R. S., Sylvania Electric Products Inc., Cincinnati, Ohio.

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Heinrichs, W. J., Southwestern Gas & Electric Co., Fayetteville, Ark.

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Shattuck, D. L., Portland General Electric Co., Hillsboro, Ore.

Student Members:
Harper, C. R., Oregon State College, Corvallis, Ore.
Rutherford, W. E., Oregon State College, Corvallis, Ore.

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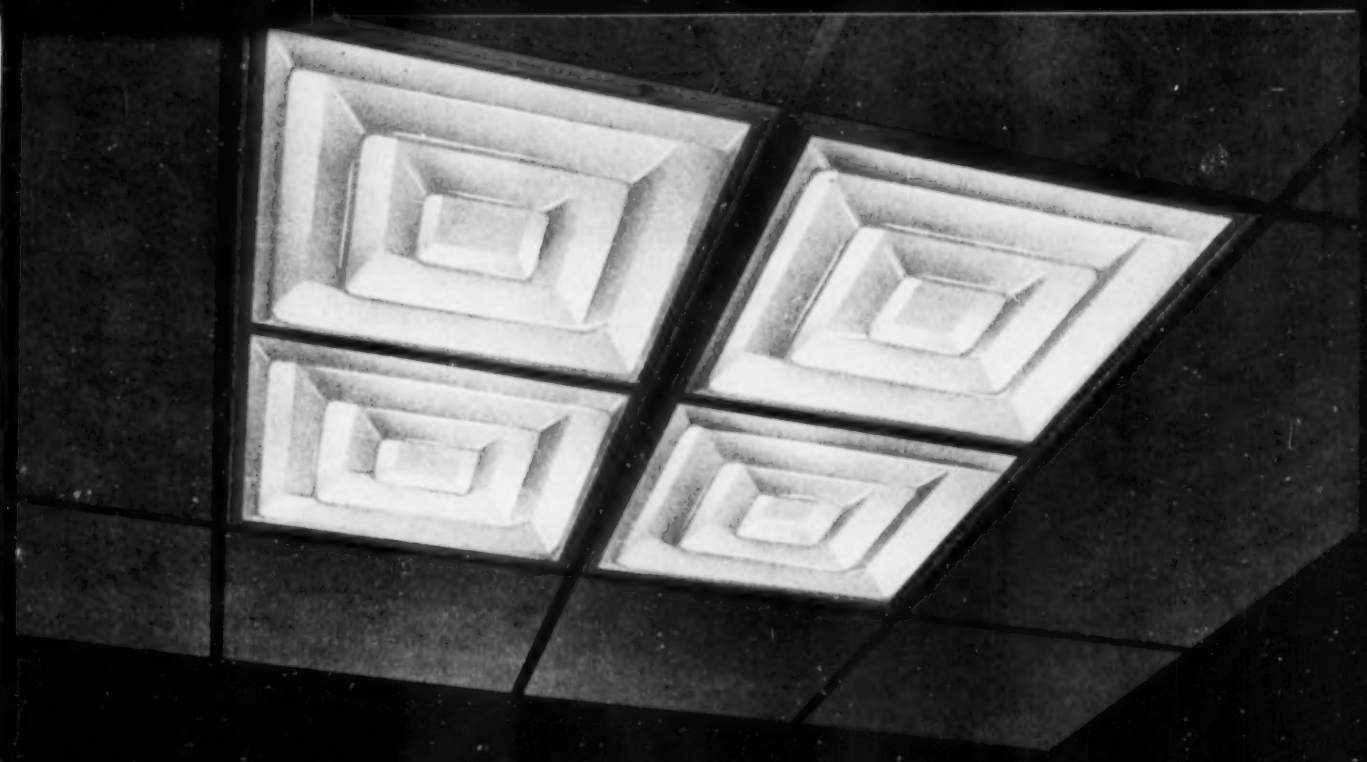
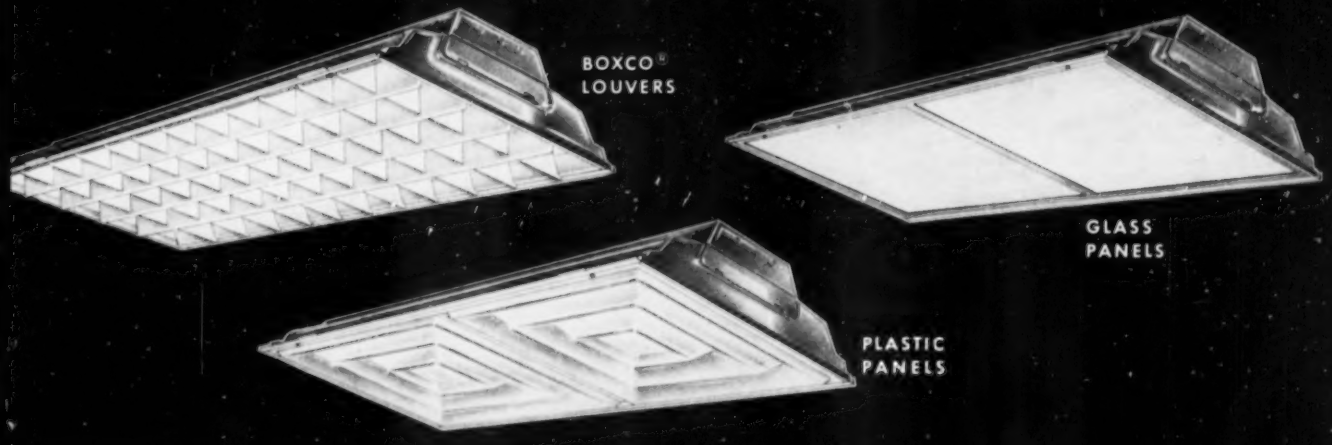
Associate Members:
Dickinson, G. C., Schuck Electric Co., Philadelphia, Pa.
Hevner, D. S., Jefferson Electric Co., Philadelphia, Pa.
Kindt, R. D., Philadelphia Electric Co., Philadelphia, Pa.
LaKornafeaux, J., Maris Equipment Co., Philadelphia, Pa.
Mucha, John, Philadelphia Electrical & Mfg. Co., Philadelphia, Pa.
Rigler, W. H., Westinghouse Electric Corp., Philadelphia, Pa.
Speed, W. G., Philadelphia Electric Co., Philadelphia, Pa.

(Continued on page 39A)



For recessed lighting in low-cost suspended ceilings

...use Day-Brite MOBILEX®



MOBILEX is a new idea in lighting—a recessed fluorescent lighting system designed especially for use with the newly developed grid-type suspended ceiling. MOBILEX is flexible. Use as single units . . . or create countless patterns of light. Available in 2′x2′ and 2′x4′ units.

MOBILEX is easy to install. Insert fixture into grid opening and let it rest on grid rails. No hangers. No suspension straps. Saves up to 50% in installation time. Get the full MOBILEX story. Write today for Bulletin OD-567.

"DECIDEDLY BETTER"
DAY-BRITE
Lighting Fixtures

Also available for use with other type ceilings.

331

Day-Brite Lighting, Inc., 5432 Bulwer Avenue, St. Louis 7, Missouri · In Canada: Amalgamated Electric Corp., Ltd., Toronto 6, Ontario.

NEW EQUIPMENT DATA
AVAILABLE WITH COUPON

New manufacturers' catalogs and bulletins listed below are available free to readers of ILLUMINATING ENGINEERING by mailing the coupon. Circle the numbers of those items which you want, drop in envelope or fasten securely to back of 2-cent postcard addressed to Publications Office.

1 Illustrated 24-page catalog covers renewable time-delay fuses, plug and copper link fuses and fuse holders. Technical data section tells how a fuse operates, gives maintenance hints, and excerpts from national code and dimensions. General Electric Co., Bridgeport, Conn.

2 Bulletin 132 is 40-page, two-color presentation of company's entire line, canopy shade, portable and outdoor units; recessed fixtures; wiring devices; special units and lighting accessories; including Vogue-Lites. Swivelier Co., Inc., Brooklyn, N. Y.

3 New pages for catalog holders describe three Mobilex grid-type recessed fluorescent units and CFI Day-Line unit for industrial installations. Pages give complete engineering data; construction and installation details, and wiring. Day-Brite Lighting, Inc., St. Louis, Mo.

4 Catalog No. 153 is a fully illustrated, 44-page engineering catalog furnishing initial basic information on the firm's line of all-steel adjustable framing, channels and fittings, including dimensioned drawings and engineering data. Flexa Steel Products, Inc., Chicago, Ill.

5 Catalog pages describe new V C U line of fluorescent lighting fixtures especially designed for asymmetrical lighting requirements in corridors and halls. Pages state that sidewise illumination of this fixture is very broad, and lengthwise the brightness is shielded by means of 45-degree plastic Grate-Lite louvers. The Edwin F. Guth Co., St. Louis, Mo.

6 Four-page, two-color catalog PL-720C gives details on new Gill-Glo luminaire featuring concentric ring louver of one-piece pressure molded white plastic. Folder shows complete testing laboratory report and dimensional data. Gill Glass and Fixture Co., Philadelphia, Pa.

7 32-page catalog 605 contains information on company's line of Uni-Flow fluorescent troffers featuring instant start operation and single pin lamps, available in one- two- and three-lamp units in shallow and deep troffer types with or without flange. Gives general specifications and types of shields. Mitchell Mfg. Co., Chicago, Ill.

8 Five new data sheets of a series are now available describing concentric ring luminaires for use with silvered bowl incandescent lamps, in the Super 500 and Super 1500 lines, manufactured by this company. Sheets contain full descriptions and illustrations, construction details and photometric data. Silvray Lighting, Bound Brook, N. J.

9 Three new catalogs cover company's Curtistrip line of lighting channel in three different sizes for wide variety of application; the new Coronet series of fluorescent luminaires; the Urna indirect incandescent luminaire for wall mounting in various installations. Brochures give illumination data and all pertinent information. Curtis Lighting Inc., Chicago, Ill.

10 60-page incandescent lighting catalog No. 153 is prefaced with engineering data including nomenclature, general factors in design of interior lighting systems; tables of room index; then covers company's complete line of incandescent fixtures of all types, includes installation and construction information; distribution curves and maintenance factors. Art Metal Co., Cleveland, Ohio.

11 Catalog file describes company's complete line of fluorescent fixtures for industrial, commercial, school, public buildings; gives ETL curves and installation data. Lithonia Lighting Products Co., Lithonia, Ga.

12 Illustrated 32-page bulletin, GEC-936, explains design, construction, performance and applications of company's complete line of pendent-type luminaires for street and highway lighting. Gives photometric data, distribution curves and other technical data. General Electric Co., Schenectady, N. Y.

13 "Questions and Answers about the RLM Label" is a new eight-page booklet which answers some of the most frequently asked queries about the RLM Institute in question-and-answer technique; ends with a condensed list of engineering factors involved in RLM specifications. RLM Standards Institute, Chicago, Ill.

14 Catalog pages on company's 5082 Series line of fluorescent luminaires give illumination data; details of construction and finish; information on maintenance, wiring and installation. Show suggested installation methods. Garden City Plating and Manufacturing Co., Chicago, Ill.

15 Catalog No. 52, 32 pages fully illustrated, covers service station lighting equipment; includes photos, drawings, technical data on horizontal and vertical fluorescent units for pump island lighting; sealed beam; spot and flood lampholders, accessories and other related equipment. Guardian Light Co., Oak Park, Ill.

16 Folder 600A tells of A.L.S. Slimline Industrial units, showing several special features with full dimensional and illumination data, as well as installation information and description of parts and accessories. Smithcraft Lighting Division, Chelsea, Mass.

17 Eight-page bulletin No. 605 on stadium lighting describes in detail the floodlighting of a typical outdoor athletic arena stressing the importance of using fully enclosed floodlights which are sealed against moisture and dirt. Pyle-National Co., Chicago, Ill.

18 Folder gives information on new Burlington fluorescent fixture specifically designed and engineered for store lighting; includes complete dimensional and installation specifications; illumination performance, and different combinations with spotlights. The Miller Co., Meriden, Conn.

19 "Traditional Church Lighting" is title of 12-page folio showing pendent, ceiling and wall mounted fixtures accurately designed to period motifs. Pages show wide variety of material finishes and glass panels and give complete specifications on all units. Gruber Lighting, Brooklyn, N. Y.

20 20-page manual "Planning the Modern Home Electrically" furnishes useful information on planning adequate wiring for the modern home; where to locate outlets; how many and what kind of circuits to provide for; and practical instructions on planning kitchens, laundries, and other lighting areas. Westinghouse Electric Corp., Pittsburgh, Pa.

Offer good for two months

Circle numbers wanted. Enter name and address. Clip out and mail.

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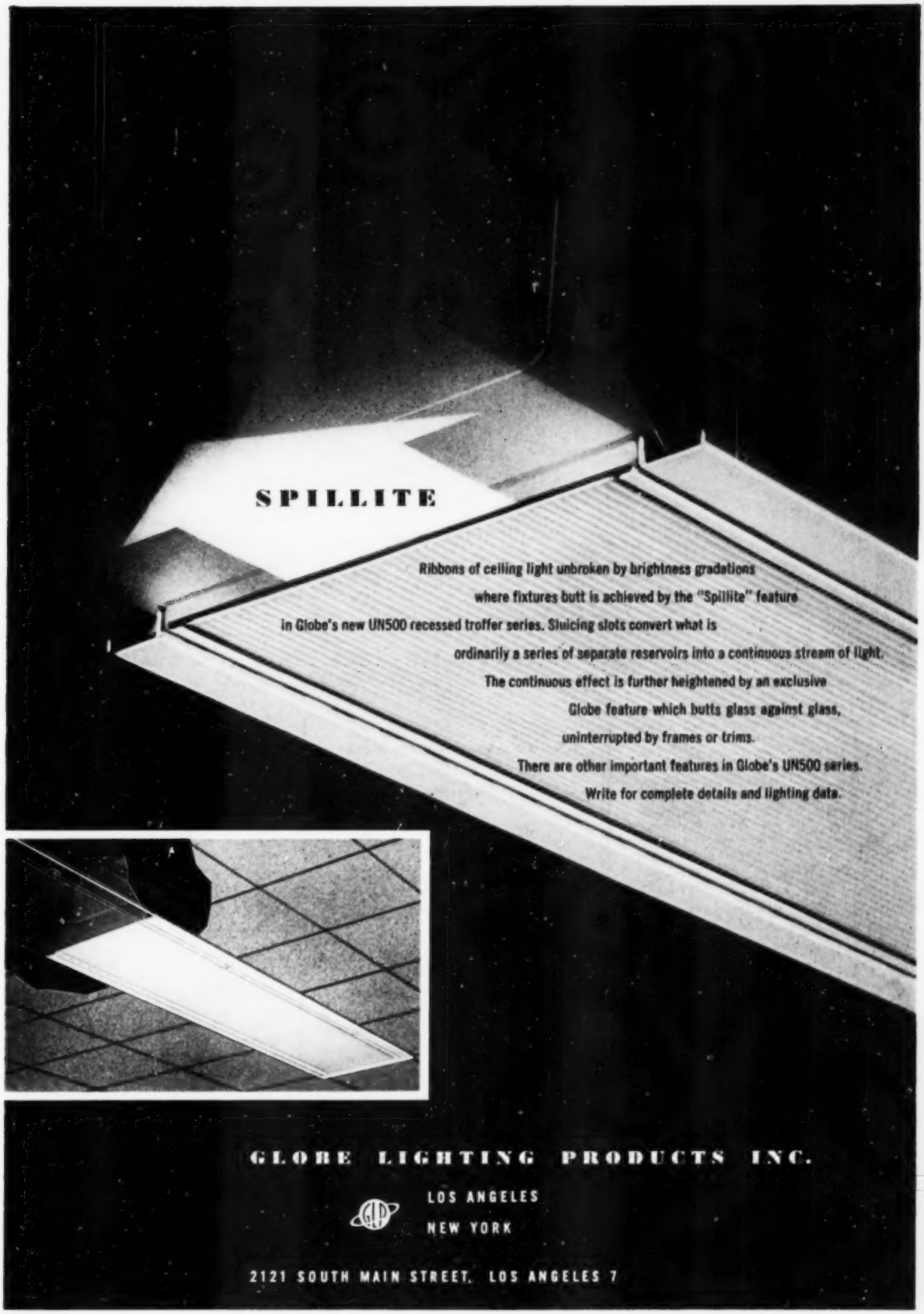
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Ribbons of ceiling light unbroken by brightness gradations
where fixtures butt is achieved by the "Spillite" feature
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ordinarily a series of separate reservoirs into a continuous stream of light.
The continuous effect is further heightened by an exclusive
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There are other important features in Globe's UN500 series.
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Where the requirements call for high efficiency plus top quality

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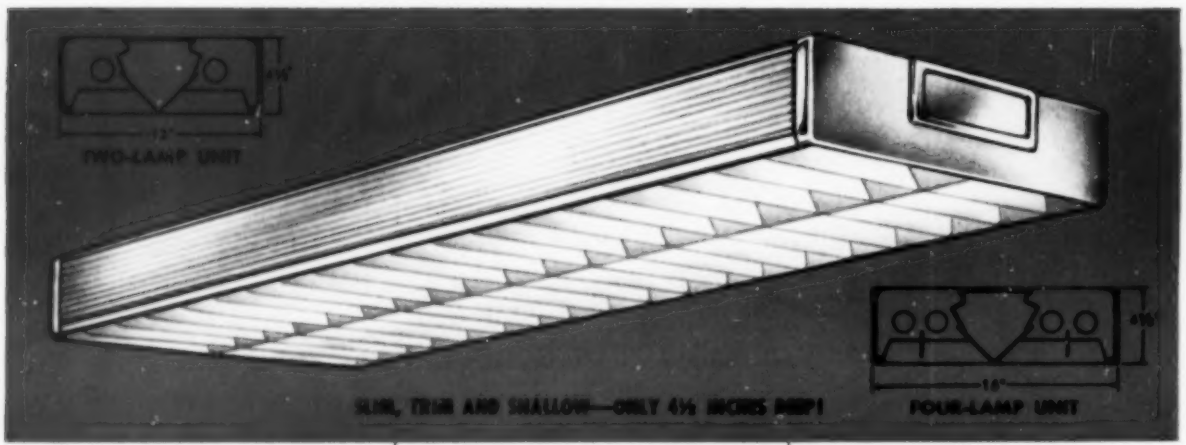
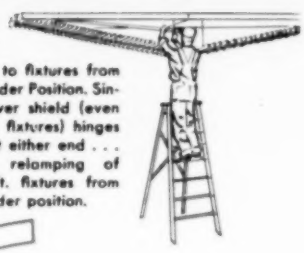
LUMINAIRES WITH ALBA-LITE GLASS SIDE PANELS



Sliding Clamp Hangers mean stems can be located anywhere on fixture. Adjustable stem (just turn to raise or lower fixture) means you have both vertical and horizontal alignment. Contractors say Garcy fixtures are least expensive to hang.

Standard "Star-Liner" units have open top. Top reflectors available to give greater downward light.

"STAR-LINER" Luminaires give a modern, built-in look . . . yet can be installed almost overnight! Priced surprisingly low—yet built with quality features for trouble-free service and easy maintenance.

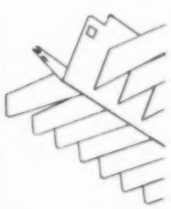


Relamp to fixtures from one Ladder Position. Single louver shield (even on 8-ft. fixtures) hinges down at either end . . . permits relamping of two 8-ft. fixtures from one ladder position.

Fixture ends are easy to wire through. Large openings simplify wiring connections for continuous runs; cut installation time.

Shielding angles: Crosswise 31°. Lengthwise 39°. Four-foot or eight-foot units. Standard fluorescent or slimline. Two-lamp or four-lamp units.

Louver cannot rattle or "sing". The V-shaped backbone of the louver exerts pressure on the cross-fins . . . holds them in a vise-like grip that prevents looseness, rattle or "sing". Louver just snaps into place . . . no screws to be manipulated.



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Sylvania Mercury Vapor Lamps offer more light . . . better light to see by . . . at lower cost.

Sylvania's line of improved mercury vapor lamps brings high lighting efficiency to municipal, commercial, and industrial installations . . . at remarkably low costs.

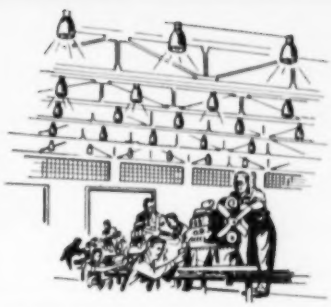
These modern lamps have an average rated life of 6,000 hours . . . many times longer than ordinary incandescent bulbs. They also offer twice the light output of incandescent types for the same amount of wattage.

As a result of this higher intensity, fewer lamps and fewer fixtures are required. This in turn means big savings in installation, maintenance and service costs, too. New illustrated folder gives complete information and characteristics concerning Sylvania Mercury Vapor Lamps. Mail the coupon for your copy NOW!

No. EH-1.
This Sylvania Mercury Vapor lamp is being successfully used today for both street lighting and industrial lighting. Rated at only 400 watts, it delivers 20,000 lumens.

For better, safer street illumination, alert municipal authorities are turning more and more to efficient, economical Sylvania Mercury Vapor Lamps.

For outdoor floodlighting, parking areas and sportslighting, Sylvania Mercury Vapor Lamps bring desired lighting intensities at desirable savings in costs.



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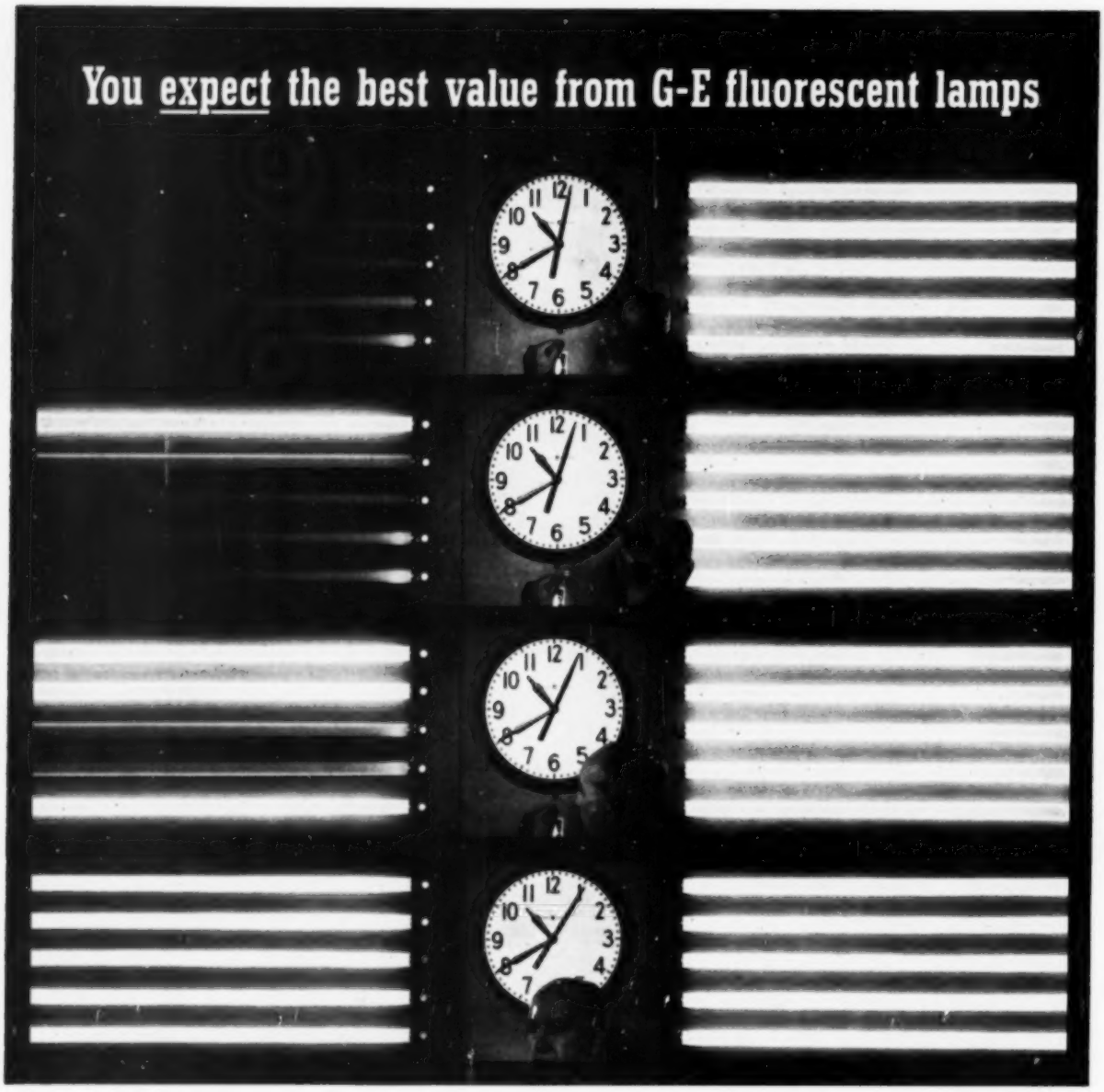


New G-E fluorescent lamp starts quicker, needs no starter

Watch the clock. Above are four unretouched photos taken about one second apart. On the left are regular fluorescent lamps, on the right the new General Electric *Rapid Start* fluorescent lamps. All were started at the same instant.

Within two seconds, all five G-E *Rapid Start* lamps are fully lighted. The regular lamps are only beginning to light.

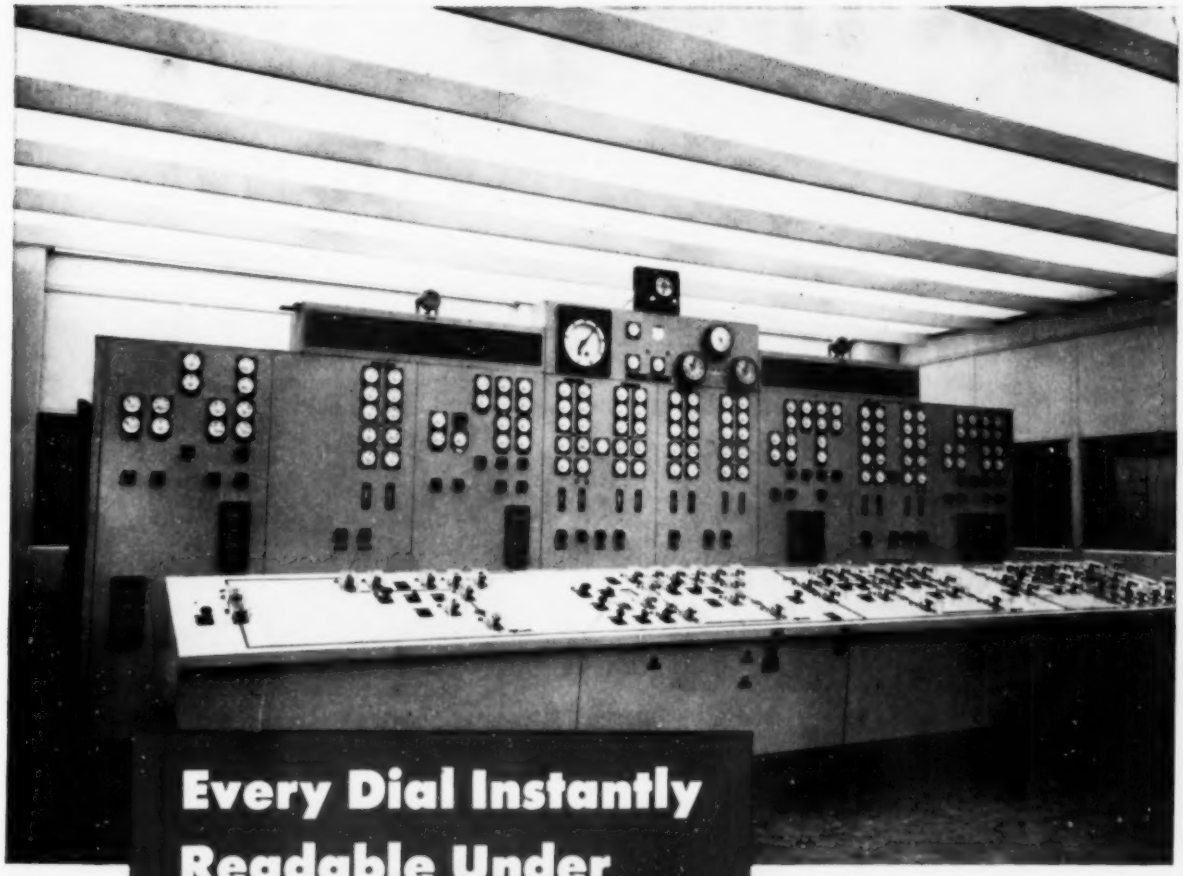
Two new General Electric developments made the *Rapid Start* lamp possible: a triple coil cathode that holds more starting chemical and a *Rapid Start* ballast that pre-heats the lamp automatically. No starter needed. No wait for pre-heating. Starting is almost instantaneous, maintenance is simpler, cheaper.

Rapid Start lamps and ballasts are now available. You *expect* the best value from G-E fluorescent lamps. Here's one more reason why you can.

For free folder, "Facts About Rapid Start" write General Electric, Dept. 166-IE-5, Nela Park, Cleveland 12, Ohio.

You can put your confidence in—

GENERAL ELECTRIC



Every Dial Instantly Readable Under a Wakefield Ceiling

Total Area:
Approximately 1,325 Square Feet

Location:
Central Control Room of a Turbine Room

Designed Initial Illumination Level
95 footcandles

Designed Working Illumination Level
55 to 60 footcandles

Lamps Used
72" and 96" T-12 430 MA lamps

Licensed Agent:
Graybar Electric Company, Inc., Chicago, Illinois

This is the central control room of the turbine room of a large midwestern manufacturer of electrical equipment. A Wakefield Ceiling provides virtually perfect seeing conditions for quick, accurate dial readings. Light is diffused so evenly through the corrugated Plexiglas "ceiling" that both direct and reflected glare are for all practical purposes non-existent.

Not only is light controlled by this Wakefield Ceiling but sound and air diffusion as well. Suspended acoustical baffles furnish excellent sound absorption; and conditioned air is delivered into the room through the multiple openings at the edges of the corrugated Plexiglas diffusers. The Wakefield "Three-Way" Ceiling is a revolutionary development in environmental control. For a detailed, illustrated booklet, complete with working drawings, write to The F. W. Wakefield Brass Company, Vermilion, Ohio.

Wakefield **Over-ALL Lighting**

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(Continued from page 30A)

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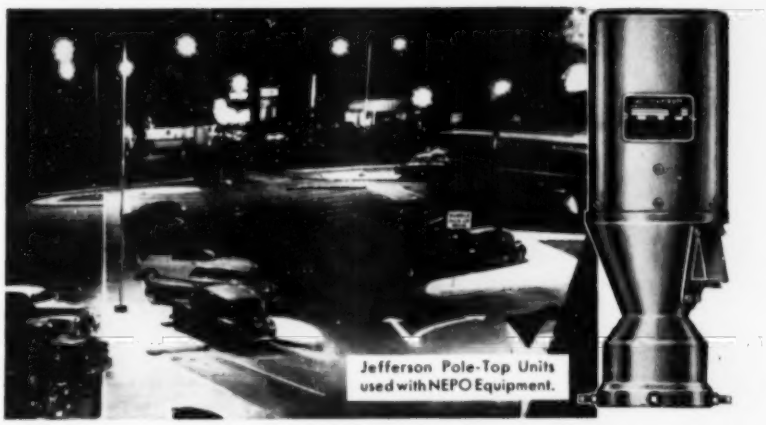

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In stores, banks, schools and offices, maximum fluorescent lighting satisfaction depends greatly on good ballasts.

Maximum light output, lamp life and dependable quiet operation are assured when you specify Jefferson Ballasts. There's a better built Jefferson Ballast, normal or high power factor design, to operate every standard size of fluorescent lamp. One and two lamp high power factor ballasts for all types and sizes of Slimline Lamps. Included in the line are Series Sequence and Lead-Lag designs. All are E.T.L. and U.L. approved. Write for new Ballast literature.

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ABOLITE

• Cooler, cleaner lighting plus longer lamp life. That's what you can expect with the new ABOLITE "All-White" lifetime, porcelain enameled fixtures. The ventilating slots provide automatic air circulation, prevent dust from fogging lamp and reflector.

Ask your wholesaler for complete details.

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THE JONES METAL PRODUCTS CO.
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ANTI-STATIC #79

★ Keeps Plastics Dust-Free; Lint-Free.
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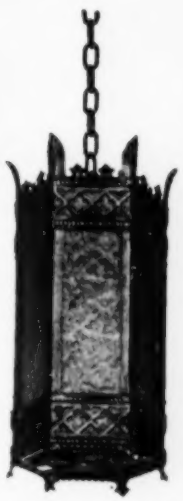

of genuine bronze or wrought iron, for churches, schools, banks, and public buildings, to your order or to architects' specifications. No order too large, none too small. M-W metal-craftsmanship has a nation-wide reputation for highest quality.

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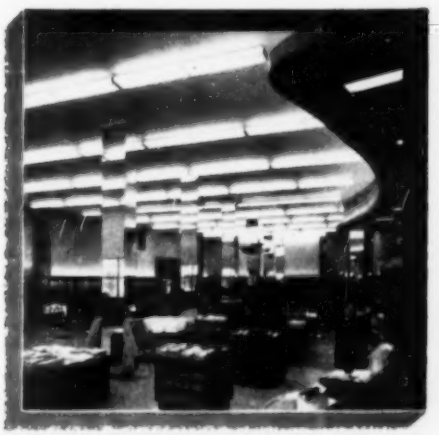

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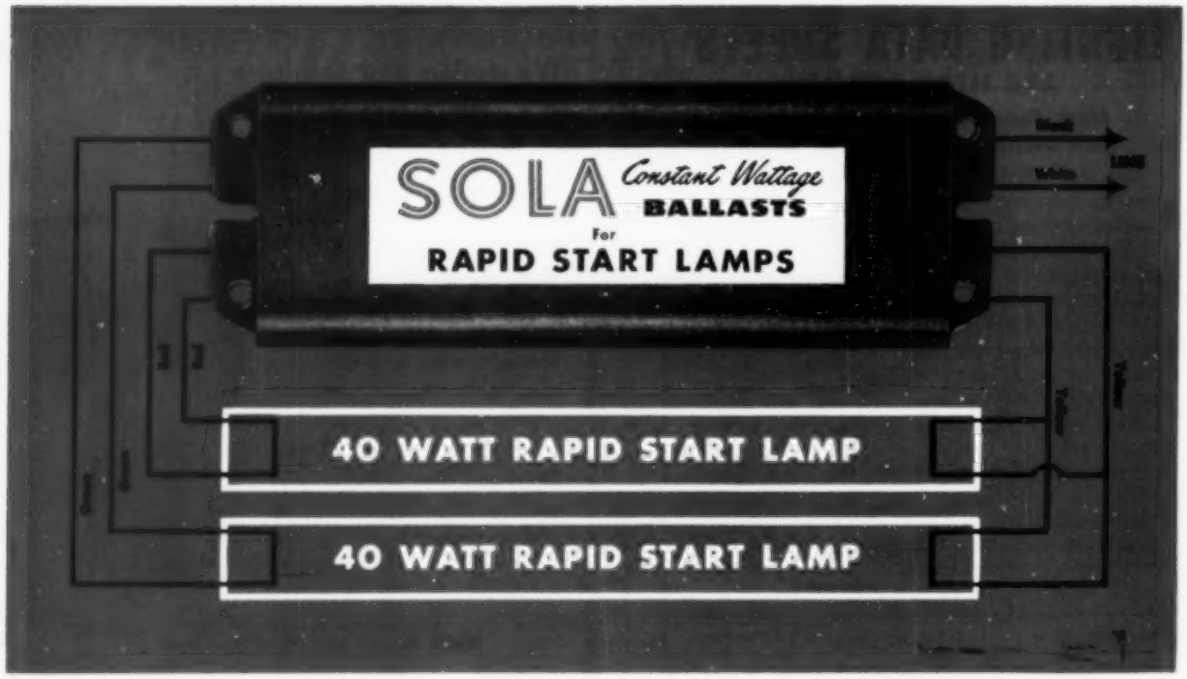
Store lighting, today, is more than the attainment of high levels of illumination for comfortable seeing. It requires advanced illuminating engineering to install a lighting system, balanced to bring out colors and textures, that will create "atmosphere" and add dramatic accents to merchandise for assured sales appeal. This depends directly upon the versatility of the luminaire design and its flexibility for light distribution control. Certified by photometric tests, Sunbeam fluorescent and incandescent commercial fixtures meet the demands of good store lighting. Typical of many Sunbeam lighting installations, the aesthetic effectiveness and practical solution to the illumination of two modern stores is shown here. See your leading electrical distributor for Sunbeam's complete line of lighting fixtures.

SUNBEAM visionaire

SUNBEAM LIGHTING COMPANY
777 E. 14TH PL. • LOS ANGELES 21, CALIF.



Here is *the lighting system* that automatically, unfailingly

maintains the performance you specify

The rapid start lamp and the Sola Constant Wattage Ballast together form the heart of an entirely new fluorescent lighting system. All the inherent advantages of the rapid start lamp are enhanced when operated from a Sola Constant Wattage Ballast regardless of line voltage conditions. This is the finest ballast that Sola Electric Co. engineers have ever created, and they have introduced a notable number of ballast "firsts." Here is a unique lighting system resulting in performance that is unsurpassed from any point of view. Check the list below. Compare and you will specify Sola Constant Wattage Ballasts for your rapid start lamp installations.

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Accelerated life tests indicate exceptionally long lamp life relatively unaffected by the number of starts . . . radio interference suppressed . . . completely safe during lamp changes . . . unusually quiet . . . positive light upon closing switch.

ARCHITECTS:

Constant light output within ±2.5%, with line voltage variations as great as ±10% . . . cooler operation (average heat rise 50°C) for reduced air conditioning load . . . UL listed . . . meets proposed Certified Ballast Manufacturer's specifications and every suggested requirement of major lamp manufacturers.

FIXTURE MANUFACTURERS:

Lower initial costs compared with instant start . . . simplified wiring . . . permits use of conventional bi-pin lamp holders with absolute safety since the circuit of the ballast is self protecting against shock hazard . . . series type circuit which has been recommended for rapid start lamps by major lamp manufacturers.

CONTRACTORS:

Only two wires, directly from the ballast, to connect on the line, no wiring to lamp sockets . . . ballast has extremely long life since it is very cool in operation . . . self protecting under abnormal conditions, when lamp failure occurs the ballast actually runs cooler, not hotter . . . gives your customer *all* the light he pays for because of constant wattage feature.

SOLA *Fluorescent* BALLASTS

WRITE FOR RAPID START BALLAST BULLETIN C-PFL-167. If you want more information, write or phone the nearest Sola office listed below.

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WILLIAM H. STERN, *President*
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Experience is proving it pays to insist on CERTIFIED BALLASTS because they assure—

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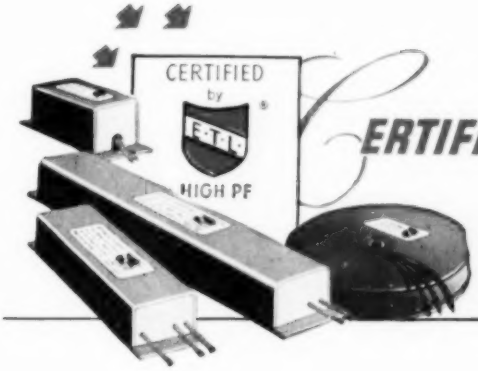
CERTIFIED BALLASTS are made by 10 leading manufacturers to precise specifications, then tested by Electrical Testing Laboratories, Inc., which certifies they conform to these high standards.

Write for complete information on the types of CERTIFIED BALLASTS available from each participating manufacturer.

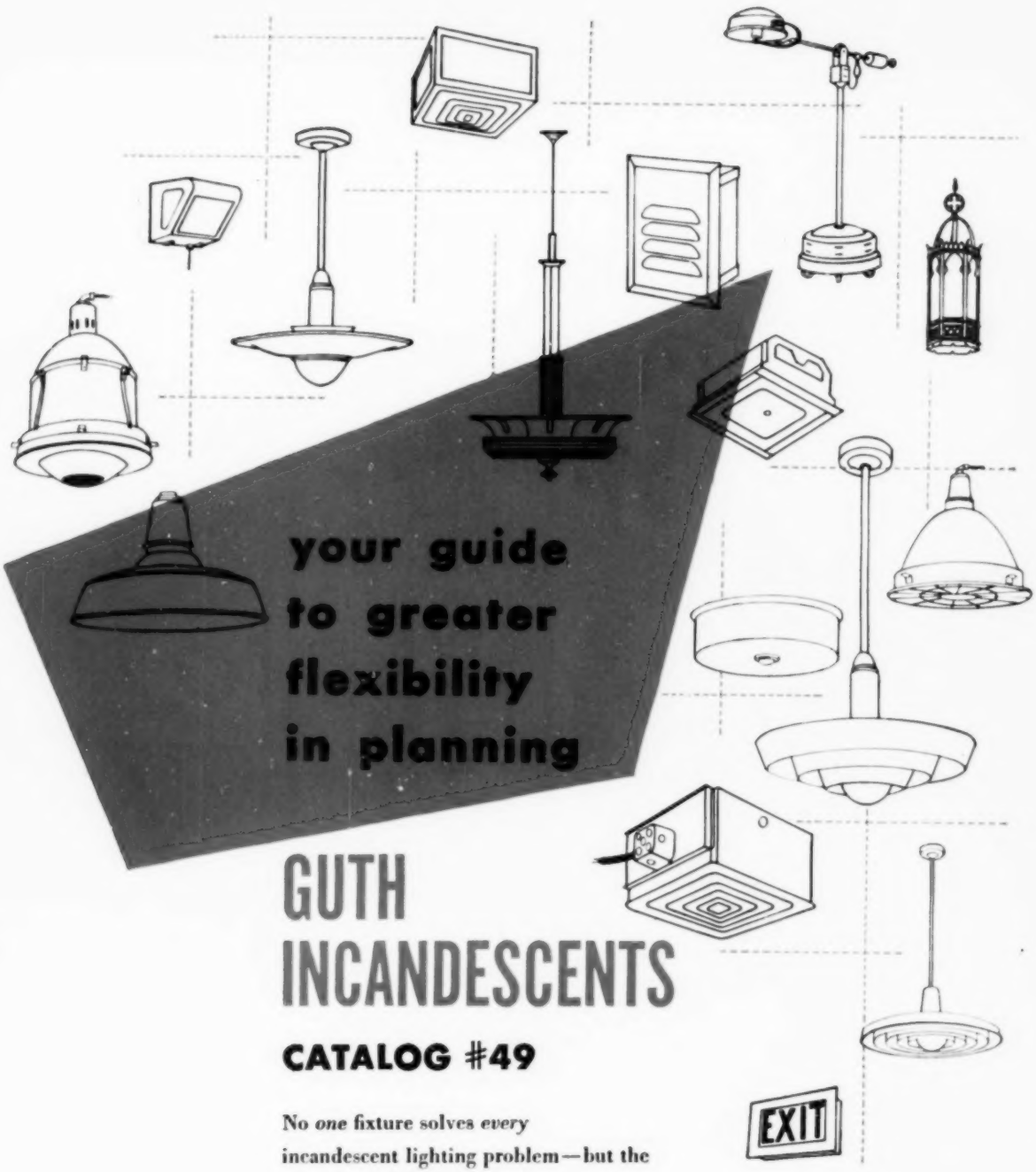
Participation in the CERTIFIED BALLAST program is open to any manufacturer who complies with the requirements of CERTIFIED BALLAST MANUFACTURERS.



CERTIFIED BALLAST MANUFACTURERS

Makers of Certified Ballasts for Fluorescent Lighting

2116 KEITH BLDG., CLEVELAND 15, OHIO



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